

PHILOSOPHICAL
CONVERSATIONS:
OR, A NEW
SYSTEM
OF
PHYSICS,

By Way of DIALOGUE.

With Eighty Nine COPPER PLATES.

Written in French by Father *REGNAULT*
of the SOCIETY of JESUS.

Translated into English and illustrated with NOTES

BY

THOMAS DALE, M. D.

In Three VOLUMES.

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MDCCXXXI.

THE

REPORT

OF THE

COMMISSIONERS

OF THE

LAND OFFICE

IN RESPONSE TO A RESOLUTION OF THE HOUSE OF REPRESENTATIVES, PASSED MARCH 10, 1850.

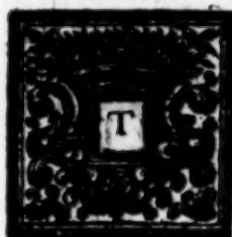


TO

Sir HANS SLOANE *Bar.*

President of the COLLEGE
of PHYSICIANS, and of
the ROYAL SOCIETY.

S. I. R.



On be inquisitive into the
Works of God in the
Creation, is most wor-
thy of a rational and
intelligent Being; to em-
ploy our Thoughts upon this Subject
is to cultivate the highest Principles
and best Inclinations of our Nature.
Productions of Art indeed at first strike
us with Admiration and Delight, but
then their Beauty is of no long Dura-

DEDICATION.

tion, and that, which before appeared so very lovely and charming, in a short Time becomes greatly unsatisfactory and distasteful. On the contrary, the Works of Nature are capable of affording us a solid and more lasting Entertainment. With what Pleasure do we survey those numberless Orbs rowling over us in the most regular and harmonious Order; with what Delight do we trace the Comets (those fiery Bodies that strike such Terror into vulgar Minds) through Worlds unnumbered and unknown? And how does this Pleasure and Delight rise upon us, when we imagine those several Orbs furnished with a rich Variety of Inhabitants, as is a very reasonable Supposition, considering that not the least Spot of this our Earth is without its Domesticks? Such Speculations not only afford infinite Satisfaction to inquisitive Minds, but lead them naturally on to the Contemplation of that greatest and best of Beings, *who knoweth the Number*
ber

DEDICATION.

*ber of the Stars, and who calleth them
by their Names.*

IF we descend into our selves and take a View of our own Bodies, we shall there find the several Parts adjusted in such a regular Manner, and so exquisitely well adapted to answer all the Ends and Purposes of Life, that he must certainly be very slow of Understanding, who is not immediately convinced of his being the Workmanship of an infinitely wise, good and powerful Artist. Farther, should we extend our Views all around us, and run over the several Species of Animals, Plants and Insects that inhabit and adorn this our Globe, should we endeavour to trace the Footsteps of divine Wisdom in the Order, Harmony and Uses of every one of them, we should soon find ourselves lost in an endless Pursuit, and readily cry out with the *Psalmist, Who*

DEDICATION.

can search out the Almighty or his Works to Perfection!

IN short, the Study of natural Philosophy fills the Mind with vast and sublime Ideas of the first Cause and Original of all Things, and is the best Means to preserve it from *Atheism* on the one Hand, and *Superstition* on the other.

BUT I would not be thought to say this to You, Sir, in Commendation of a Study, which has been so remarkably encouraged by your Patronage and Example; it is natural to indulge one's Sentiments upon a pleasing and agreeable Subject.

IN the following Work, which I have now the Honour of inscribing to You, I can claim little more than the Merit of having been, as I hope, a faithful Translator. In the Original our Author has given good Proofs of
his

DEDICATION.

his Industry and Abilities, but then he has at the same Time abundantly shewn how difficult it is to efface Notions and Impressions received in our earliest Education. However this is not so much to be wondered at, if we reflect how many Men of Learning and Reputation, even amongst ourselves, labour under the same unhappy Circumstances. In Order therefore to remedy this Evil, I have taken Care to intersperse the whole Work with proper Notes, founded upon the Principles laid down by that illustrious Ornament of our Nation, the incomparable Sir *Isaac Newton*.

I SHALL not pretend, Sir, to copy the usual Forms of Dedications, being thoroughly apprized how difficult a Task it would be, even to attempt the Praise of a Gentleman, who has deserved so well of the Learned World. Such a Subject would prove superior to much abler Pens.

DEDICATION.

WHEREFORE as in this Case, *Silere præstat quàm pauca dicere*; I shall content my self with the Honour of being esteemed,

Sir,

Your most obliged and

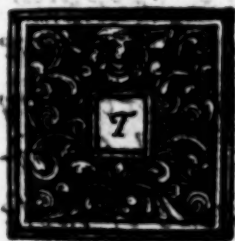
Obedient humble Servant,

THOMAS DALE.

THE



THE
TRANSLATOR'S
PREFACE
TO THE
READER.



*HE many great Improve-
ments that have been of
late made in natural Know-
ledge, have induced a Va-
riety of Persons to turn
their Speculations this Way. That
immortal Reputation which Sir Isaac
Newton acquired by his Writings, has
so*

P R E F A C E.

So far excited the Curiosity of many who are involved in the Hurry of Business, as to set aside some Part of their Time, to inform themselves of his surprising Discoveries. Even the Belles forego their darling Quadrille, and are proud of being accounted Disciples of this great Man; and the Beaus in Compliance with the Fashion, are tempted to resemble rational Creatures in something more than the exterior Form.

But since it requires a greater Knowledge in the Mathematicks than most Persons are blessed with to read Sir Isaac Newton with any Success, many able Pens have been employed to set his Works in a more popular View; some of whom, I confess, have gained much Reputation and Esteem by their Attempts, and others no less private Emolument. Yet still none of these Writings were sufficiently divested of Lines and Figures to be generally useful and instructing; wherefore I have diverted myself for some Time past at my
vacant

P R E F A C E.

vacant Hours in translating the following Work, which I now present to the Publick. It is drawn up by Way of Conversation, which Manner of Writing seems best suited to set Truth in the easiest Light, and insensibly to instil Knowledge into the Mind of the Reader. The ingenious Author has run thro' the whole Circle of natural Knowledge, and collected a great Number of curious and entertaining Experiments, many of which are taken from the Memoirs of the French Academy; so that the English Reader has here an Opportunity of seeing the several Discoveries that have been made by the Philosophers in France. But tho' these Experiments are agreeably related, yet are the Facts oftentimes but very unluckily accounted for; which is owing to our Author's strong Attachment to the Sentiments of Des Cartes, which have been long since overturned by the Demonstrations of Sir Isaac Newton; and tho' our Author, as appears from the following Sheets, was not wholly

P R E F A C E.

wholly unacquainted with the Writings of that great Man, yet were the Prejudices of Education so prevalent as to exclude all Conviction. By this we see there may be Bigots in Philosophy as well as in Religion. However, to remove this Inconvenience, I have subjoined the Principles of the Newtonian Philosophy by Way of Notes (after the Manner of the late learned Doctor Clarke in his Edition of Rohault) by which Means the Reader will have the Pleasure of comparing the Old Philosophy with the New, and of perceiving the Advantage of the latter, by applying it to the Experiments before him. If this Work should succeed, according to my Wishes, in the Instruction and Entertainment of the Reader, I shall think my Pains sufficiently answered; if not, the Goodness of my Intention will justify the Undertaking.

THE



THE CONTENTS.

THE Introduction. — Page 1

CONVERSATIONS.

- I. Upon the Nature of Physics, and the general Principles of Bodies. — 5
- II. Concerning the Existence of Bodies, and the Air in particular. — 18
- III. Upon the Existence of the subtile Matter. 27
- IV. Upon the Porosity of Bodies. — 35
- V. Concerning a Vacuum. — 45
- VI. Upon the Nature of Motion. — 57
- VII. Upon the Properties of Motion. 70
- VIII. Upon the general Rules of Motion. 87
- IX. Upon the Hardness, Elasticity, and Softness of Bodies. — 118
- X. Rules of Percussion in hard Bodies. 134
- XI. Upon

The CONTENTS.

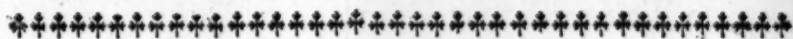
XI. Upon the Percussion of elastic Bodies.	141
XII. ————— Soft Bodies. —	154
XIII. Upon the Sphere. —	158
XIV. Upon the Earth and Minerals.	172
XV. Upon the Loadstone. —	196
XVI. Upon the Communication, Inclination, and Declination of the Loadstone. —	216
XVII. Upon Gravity. —	233
XVIII. The Resolution of several Problems upon Gravity. — —	251.
XIX. Upon the Nature of liquid Bodies.	262
XX. Upon the Gravity of liquid Bodies.	269
XXI. Upon Hydrostatics, or the Æquilibrium of liquid Bodies. —	289
XXII. Upon the Gravity of the Air, and its Ef- fects. — —	307
XXIII. Upon the Effects of the Spring of the Air. — —	325
XXIV. Divers curious Effects of Gravity and Elasticity of the Air in different Bodies.	38
XXV. Concerning Syphons and Capillary Tubes.	350
XXVI. Upon Fire. —	360
XXVII. Upon Gunpowder. —	378



PHILOSOPHICAL CONVERSATIONS

BETWEEN

Aristus and Eudoxus.



INTRODUCTION.



INCE the Academies of *Paris*,
London, *Italy* and *Germany*, and
the most happy Genius's of *Eu-*
rope, at once animated with the
Love of Truth, the Commenda-
tions, Favour and Beneficence of Princes, have
united their Endeavours to disclose the Secrets

VOL. I.

B

of

of Nature, Philosophy has its Charms and its Graces: It pleases, is universally admired, beloved, and every where favourably received, even at the Court it self.

Eudoxus has been particularly delighted with this Study from the Time he was first capable of relishing it. Since that Time no Employment was so pleasing to him, as to admire the Strokes of divine Wisdom manifested in the Structure and Beauty of the Universe, and study those secret Recesses which display so many Wonders to our Eyes.

The Light which discovered to him the Heaven and the Earth, the Sight of a Fountain, a Flower or an Insect was capable of entertaining and delighting him all the Day long. A Sky brilliant with Stars made the Night appear to him as beautiful as the Day. Should Darknes or thick Clouds veil the Sun from his Eyes; should the Rain succeed to a serene Sky, a Tempest to a Calm; his Enquiries into, and Apprehensions of the different Causes which produce these Vicissitudes and various Effects, ever afforded him a new Pleasure. In the Height of Winter amidst his philosophick Meditations, even the Rigour of the Season presented to his curious Mind such surprizing Changes, as made him forget the Flowers of the Spring, and the Fruits of Autumn, and made him some Amends for the absent Pleasures of the most smiling Seasons. He could not conceive how a Man could deny himself
the

the Pleasure of employing his leisure Time in contemplating the Hand of the Creator, even in the smallest of all visible Beings. The Sight of Truth infused into his philosophick Soul Pleasures perhaps as piquant, at least more pure, as well as more solid, than those which are tasted at the most agreeable Feasts in the World. Thus the Joy which overflowed his Heart, seemed to diffuse itself over his whole exterior Form. His Air was affable, and his Manner engaging. There was nothing austere in his Philosophy: It was natural, equally grave and Pleasant, and procured him the Esteem, the Confidence, and Friendship of *Aristus*.

In the Person of *Aristus*, were united all the Graces of the Mind, together with those of the Body. He was a young Man, who was entirely free from the Vices of Youth. He was born a Philosopher, an Enemy to that soft Idleness in which so many Youths languish, who are wholly taken up with unreasonable Pleasures, vain Amusements, Comedies and Operas, bounding their Knowledge, at most, with being able to write a Madrigal or a Song, in catching the Airs of some *Petit-Maitre*, or the Pleasures of the Bottle. Nature, Birth and Education had inspired the Soul of *Aristus* with Sentiments far more noble; he saw nothing more worthy of Man, than the Knowledge of himself, and every Thing that surrounded him. In the Flower of his Age, and in the Season of Pleasures, he

had a more ardent Passion for the Discovery of the Source and secret Causes of Things, than he had for Pleasure itself. The Esteem which he found the Philosophers of the Academy enjoyed among all Sorts of Persons, whose good Opinion was of any Value, raised a noble Emulation in him. He was pleased to see Philosophy talk a Language so harmonious and delightful in their Works. But he wanted some Person versed in the reading of these Works, and already initiated into the Mysteries of Nature, to second his Taste, and facilitate his understanding the most agreeable Truths. He was charmed to find this Person in *Eudoxus*. The same Taste, the same Inclination, soon united them very strongly together, and in a Chain of continued Conversations, and which seem to arise one out of the other; they agreeably unravelled every Thing which we find the most curious and delightful in the Universe.





CONVERSATION I.

Eud. WELL, *Aristus*, your Taste then inclines you to Natural Philosophy? I like it so much the better, because I am indebted to this Inclination for the Esteem, Confidence and Friendship wherewith you are pleased to Honour me. I shall endeavour to second it. I am heartily at your Service, and should find Pleasure in being capable of procuring you any.

Arist. Nothing is more generous, than to find one's Pleasure in procuring it to others. Upon this Account I hope you will receive some Satisfaction in illuminating me with your Light; for I freely confess, that I feel an eager Desire of knowing my self, and what surrounds me and affects my Senses; and I would without any Difficulty sacrifice all the vain Pleasures which the World can present me with, to the Pleasure I take, or imagine, in this Knowledge.

Eud. The Pleasure which accompanies this Knowledge, is alone in my Judgment worth all the others put together. Even from *Cicero's* Time Physicks have been looked upon as the most pleasant, delicious and agreeable Food

of the Mind. What Allurements then must they not have at this Time, since they have been enriched with an infinite Number of new Discoveries? By the Light of this Science the Mind at once observes that Wisdom, which by certain simple but fertile Laws of Motion, prescribed and freely followed by itself, draws out of Matter this Variety, Assortment and admirable Arrangement of terrestrial, transparent, and luminous Bodies; it penetrates into the Bosom of the Earth, there it perceives after what Manner Nature forms Diamonds, Silver and Gold for enriching us; there it discovers the Origin of Winds and subterraneous Fires; it sees these Fires kindled, and the Winds formed, shaking the Earth, and spreading abroad a salutary Horror. It perceives that Force which makes the Waters ascend by a thousand Channels, even to the top of the Mountains, to form there those Springs so fit for refreshing us; it knows after what Manner the Earth being warmed covers itself with Flowers in the Spring, and sends forth Vapours, Exhalations and Clouds into the Air, and in those Clouds the Thunder and the Thunder-bolt; by what Course the Rays that come from the Sun proceed to be broken and reflected in the Clouds, so as to present us with the most beautiful Colours. From the midst of the Air it ascends to the Planets. What do I say? It bounds from one Vortex to another, even to the Extremities of the World; and from the remotest Stars,
it

it returns again to consider with a fresh Pleasure, the rapid Circulation which carries Blood and Life into all the Parts of a human Body.

Arist. This lively Description would doubtless be sufficient to engage one for ever to Physicks.

Eud. Physicks have a thousand and thousand other Charms still more capable of affecting and ravishing an attentive Mind. But since in order to follow both your Taste and mine, we purpose to run over the Whole, without dwelling but upon that Part which is most curious and profitable; let us endeavour to do it with some Order, so that our Conversations may seem to arise from one another, and the first may afford some Light into the subsequent. Perceptions which arise from one another, are both the easier, and more conspicuous.

Arist. Pray, let us begin with a clear and exact Idea of Physicks. When any one speaks, I love to know what he is discoursing upon.

Eud. Philosophy is properly the Knowledge of Bodies. Its Character is to discover to us the general Principles, Properties, and Arrangement of Bodies; the Nature and Properties of every Species of Bodies; in a Word, the Effects, and the Causes of those sensible Effects, whence that Harmony and Beauty result which our Senses admire in this vast Universe.

Arist. This Idea seems clear, distinct and beautiful. But what Principles do you suppose to reign equally in all Bodies?

Eud. Matter and Form.

Arist. Do you believe that Matter is sufficiently known by the Information of our Senses?

Eud. I know that the divine Power can and does suspend upon our Altars * the Impenetrability of Matter, or that which is the Cause why a Portion of Matter, which I call a Part or Particle, when compared with another that is greater, admits no other into it. In short, Matter is a Substance naturally impenetrable; this is universally allowed, and this is sufficient for comprehending and explaining those Wonders which affect us; is not this a sufficient Knowledge of Matter?

Arist. If Matter were not naturally impenetrable, we should quickly, I imagine, see those Wonders which affect us, disappear to the Eye; in an Instant the Earth, Stars, and Heavens would approach and penetrate one another, and by penetrating, straiten one another strangely; and we should be greatly astonished to find our selves almost annihilated, and to see the whole Universe reunited in one Point: Or rather that Universe has never had any Existence. But is it very certain that Matter is naturally extended, and that every Part has Length, Breadth and Thickness?

Eud. Two Particles, however minute, being united together, form an Extension; for if two do not, why should three or four? But

* Our Author, I suppose, alludes here to the Doctrine of Transubstantiation.

Things which have no Extension, make none by their Union. Do they touch one another? They perfectly penetrate one another, the one admits the other into it; the one has nothing without the other, seeing they touch one another in all imaginable Points; otherwise each of them would contain Particles still more minute, the one without the other, and thence would be extended without being so in Reality; but Reason acknowledges no such Contradictions in Nature. What follows from this? That every Part of Matter is extended. Therefore Matter is extended in its natural State. Geometry supports this Reasoning, and no one has yet demonstrated its Defect.

Arist. Therefore the smallest Parcel that one can imagine, must contain in it Parts more minute, even *ad infinitum*. How much every Thing that seems to approach Infinity makes us sensible that our Understanding is limited! The Mind loses itself in a surprizing Multitude of small Beings; it finds therein no more Hold. Those Nothings, if I may so call them, ought to confound the Pride of Philosophers, if they had as much as some ascribe to them.

Eud. The Imagination is lost here, rather than the Mind; for if you divide a Particle into the most inconceivably minute Parts, the Mind will always find therein something that regards the West, and something that regards the East; and what regards the West, is not that which regards the East.

After

After all, whether the Mind find in Matter Particles assignable and divisible *in infinitum*, or not, this Enquiry so famous from the first Rise of Philosophy, and which has only tormented the finest Wits in vain, can be of little other Use than to keep Philosophers modest; an Endeavour vain enough. In order to relish the Pleasure of understanding what is surprizing in those Effects, whose Marvellousness depends upon the Smallness of the imperceptible Parts, it is sufficient to know that every sensible Part of Matter contains Particles imperceptible, and smaller the one than the other, far beyond our Imagination. This is what every one knows whenever he pleases, and what may be learned from very curious Experiments.

For Garments that are perfumed with Roses preserve a pleasant Scent a long Time; a small Grain of Incense is perceivable through the whole Extent of a large Hall. A Grain of Musk, formed like a sort of Salt in the Bladder, of a kind of Roebuck, without losing hardly any Thing of its Substance, exhales for whole Years a very strong Odour, capable of enfeebling Serpents of an enormous Bigness at a certain Distance, stopping, lulling asleep, and rendering them immoveable^a. Now, how can this happen, if odoriferous Bodies do not contain almost an infinite Number of Corpuscles

^a Recueil XIV. des Lettres édifiantes des missionnaires de la C. de J. p. 493.

of an incredible Smallness, which are divided, diffused every Way, and strike the Organ of Smelling? A small Plate, a very minute Piece of Brass dissolved in Spirit of Sal Armoniac, affords a sufficient Number of imperceptible Particles to colour a Quantity of Water two hundred Times greater. Let a Drop of this coloured Water fall upon a lighted Lamp, it will be divided so prodigiously by the Heat, that for the Space of half an Hour the Flame will appear wholly blew. One Grain only of Vitriol dissolved in 9216 Grains of common Water, sensibly dyes all this Quantity with its Colour^b. But you will perhaps have more Pleasure in considering the enormous Multitude and Smallness of the Parts of Matter in Gold; the sole Idea of this precious Metal has something in it of the Flatterer.

Arist. Can one be affected with the Splendor of Gold, *Eudoxus*, when the Secrets of Matter are unveiled to the Eye, and one has a Taste for Truth? I would venture to lay any Sum of Gold imaginable, that a Philosopher, like you, would find more Pleasure in knowing it well, than in possessing it.

Eud. A Philosopher, like me, lays hold on Things as they come; he possesses without Covetousness, but yet he possesses, being less affected with his Possession, than with an Enquiry of *M. Robault's*. This Gentleman^c by

^b Mem. de l'Acad. 1706. p. 413.

^c 1. Par. c. 9.

Calculation found in a cubical Foot of Gold, 21584 Ounces, in every Ounce more than four Millions of Lines; in every Line, how many Points or more minute Particles might the Mind still see? Have you never seen them draw Gold in *St. Dennis's-street*?

Arist. I have, and was astonished. The Drawers have a Silver Cylinder of about fifteen Lines in Diameter, and 22 Inches long, covered sometimes with about six Ounces, sometimes with about one Ounce of Leaf of Gold, inseparably attached to the Silver, by Virtue of the Heat, and the rubbing of the Blood-Stone. At first they make one End of the Cylinder or Ingot, enter into the biggest Hole of the Wire-drawer, which is a Plate of Steel pierced through with a Number of Holes. Then they lay hold on it with Gags fastened to a Cable drawn by a Capstane, which is turned round by five or six Men: The Cylinder passes through, and is lengthened in passing; then they run it successively through an hundred and a hundred Holes, proportionably smaller the one than the other; and at last passing through Holes almost imperceptible, the gilded Ingot or Cylinder becomes a Thread of Gold, which is properly nothing but a Silver Thread gilded, which is afterwards wrought upon Silk, to support the Luxury of rich Attire, and cherish the Vanity of those who deck themselves with Threads of Gold, without observing

serving what those Threads have in them more worthy to engage the Attention.

Eud. According to the Calculation of *M. de Reaumur*, a celebrated Member of the Academy^d, an Ingot of Silver of 45 Marks, and which was only 22 Inches long, gained 13963240 by being drawn into Wire; imagine then what a Number of imperceptible Parts there must be in so small an Extent!

Arist. Here I equally admire Nature and Art; Nature in the wonderful Ductility of Silver and Gold, and Art in the wonderful Effects which it thence draws, and which we take no Notice of, because they are continually under our Eyes.

Eud. This is yet nothing. This single Ounce of Leaf-Gold laid upon the Silver Cylinder, is drawn out into Gold Thread by the Wire-drawer, and is lengthened enough upon the Silver to equal the Length of 100 Leagues, and unite *Lyons* to *Paris* by a sort of Golden Chain. It is likewise possible by Art to lengthen it out to 120 Leagues of 2000 Fathoms each.

Arist. But what then is the Thickness of the Gold in Places where the Thread is least gilt?

Eud. Perhaps one Million and the fifty thousandth Part of a Line. When the Business is only to divide a Piece of Gold of one

^d Mem. de l'Acad. p. 201.

14 CONVERSATION I.

Line into a Million different Leaves; it is but a Trifle.

Arist. What surprizing Smallness of Particles!

Eud. What surprizing Smallness, say you? Nay I tell you that those small Beings, whose Smallness astonishes you, are immense, and even Colosses when compared with Millions of other Beings. The Smallness of a Mite, which perhaps is the least of sensible Animals, is but little inferior to that of the Particles of Gold; and *M. de Malezieu*, saw with a Microscope, living Animals 27 Millions of Times smaller than a Mite^c. Through their transparent Skin he perceived Bowels, Eggs, the Forms of their *Fœtus* or young ones, and a sort of Blood circulating by contrary Motions. These Animals, 27 Millions of Times less than the least perceptible ones, must then have in their almost infinite Smallness, Eyes, Feet, Intestines, Veins, Arteries, an Heart, and Blood. The finest Particles of their Blood are probably to their Bodies, as the finest Particles of our Blood, called animal Spirits, are to ours. The finest Particles of our Blood, are almost infinitely smaller than our Bodies; therefore the finest Particles in those animated Beings are almost infinitely smaller than their Bodies, which are 27 Millions of Times less than a Mite. Well, *Aristus*, would your philosophical Imagination desire,

^c Hist. de l'Acad. 1718. p. 19.

for its Satisfaction, Particles yet more minute, and penetrate still farther into the imperceptible Principles of Matter?

Arist. I own it, my Imagination loses itself here in the enormous Smallness of those Particles; but it loses itself, I believe, without going astray: For the Moment it is lost, through want of finding an Hold, it encourages my wavering Mind, and emboldens it to acknowledge in Matter, Particles still more delicate, even to Infinity.

Every Thing conspires to persuade me, that Matter is a Substance naturally impenetrable and extended. Can any one not agree to it? But Matter, which in its natural State presents nothing to the Mind but Length, Breadth, and Thickness, has nothing of itself to rank it under one Species of Body rather than another: What then is this second Principle of inanimate Bodies, this Form, which of a Portion of Matter makes one Species of Body rather than another; Gold rather than Silver, a Diamond rather than Crystal, a Pink rather than a Tulip, and a Tube-rose rather than a Rose?

Eud. It is the Configuration, the Arrangement, and the Texture of those Parts, whose Smallness escapes your Imagination, and seems, as it were, to be lost in Non-entity. For imagine only in several Portions of Matter divers Configurations, Arrangements, and Textures of the imperceptible Parts, and you will conceive several Species of Bodies; for Example,
Marble,

Marble, Agate, or Pearl. Do not we see Bodies pass from one Species to another, without any other Change than a new Texture of the imperceptible Parts? The Agitation of Fire produces nothing else in Salt and Sand when melted together; and yet these two Bodies thus melted, constitute Glass proper for defending us from the Injury of the Air, without denying us the Use of Light. The Juices of the Earth are not Plants of themselves; but should they be ranged differently, they become different Plants; these Juices being agitated by the natural Heat, insinuate themselves into divers Buds; and according to the various Structure of the Fibres and small Cells they meet with therein, they are turned, modified, placed, and ranged after a Thousand Manners. Thus of Juices, nay often of the very same Juices, are formed the Violet, the Anemone, the Ranunculus, and that charming Variety of Flowers, with which our Meadows and Gardens are enamelled in the Spring. Now, since the different Texture of imperceptible Particles constitutes different Bodies, it is likewise sufficient for the Form of those Bodies; Why then should it be sought for elsewhere?

Arist. I love to see you introduce Flowers into your Discourse, *Eudoxus*; it makes your philosophical Sentiments appear the more delightful. Your Flowers please me, but yet I am more affected with your Reasons. To them
I yield

I yield with Pleasure, and it is indeed impossible to refuse one's Assent.

Eud. What then in general, according to your Opinion, are those different Bodies, whose Aspect cheers our Senses?

Arist. They are so many Portions of Matter, whose imperceptible Parts have their proper Configuration, Texture and Arrangement.

Eud. I think we have sufficiently dived into the Nature of Bodies in general. To Morrow we will see if there are any Bodies in the Universe.





CONVERSATION II.

*Concerning the Existence of Bodies, and
the Air in particular.*

Arist. CAN one demand seriously, *Eudoxus*, whether there be any such Things as Bodies existing? The sole Pleasure of seeing you, speaking to you, and hearing your Voice, cannot in the least permit me to doubt it. They tell us indeed ^f that certain *Indians* acknowledge only Spirits; but those *Indians* are Infidels, who are deluded by the Spirit of Darkness. Could ever any one be found in *Europe*, out of a Madhouse, who acknowledged nothing in this vast Universe but Phantoms of Bodies?

Eud. When we are not upon our Guard against new Notions, we easily suffer our selves to be imposed upon. We form to our selves new Principles; and hence the most ridiculous Consequences procure our Assent without Contradiction. The most whimsical Imaginations become familiar to us; our Vanity finds a Satisfaction in thinking after an unusual Manner.

^f Dans les Lettres édifiantes des Missionnaires de la C. de J.

This Snare hath drawn more than one modern Philosopher into the Folly of the *Indians*. The Abbot * * * makes no Mystery of it, he acknowledges in himself only one half of himself; and notwithstanding the Weight of his Body, which seems to revenge this Affront by the Pains it causes to the Soul, without deliberating he looks upon himself as a pure Spirit, which without a Body receives according to I know not what imaginary Laws of Nature, the Impressions which it would receive if there were Bodies, and if he had one himself.

Arist. Probably that he may act in a suitable Manner, and carry on his new Philosophy to the utmost, he neither eats nor drinks.

Eud. Oh! herein you are much mistaken, he eats and drinks better than any Body. The Wines of *Tonnerre* or *Champagne*, and Pheasants or *Ortolans*, have nothing in them too material for this pure Spirit. He loves Concerts, Shows, Comedies and Operas. You may oftner see him in Circles of corporeal Beauties, than at the Foot of the Altar, contemplating the Beauty of the purest of Spirits. He never denies himself the honest and lawful Pleasures of Sense; yet when he tastes them in Reality, he thinks he only enjoys them in Idea. Sometimes we take Delusion for Reality; he takes Reality for Delusion, but loses nothing by it, except the Reputation of a wise Man, by Virtue of his being a Philosopher.

Arist. He has lost more in my Judgment ; he has lost the Truth. For, in short, the Scripture which contains the holiest Maxims, the noblest Ideas of the Deity, and a Worship most worthy of God; the Scripture, which cannot deceive us, teaches us that there are Heavens, Earth, Plants, Waters, Seas, Men who ought to feed upon the Substance of a God-Man, an Air which Men breathe, a Moon, a Sun, and Stars ; all Beings created by the Hand of the Almighty. Can these created Beings be only ideal Beings? Can they only exist in my Mind, or in the Ideas of God, that is to say, be created without being created?

Eud. Do you believe that without the Assistance of Faith one can rightly know the Existence of those Beings?

Arist. I am convinced of it: We know it without the Assistance of Faith, if the constant Information of our Senses, an unavoidable Bias engraven on our Souls by the Author of Nature, the Idea of God and Reason, all concur to teach it us. In an important Affair, where the Question is about knowing whether we owe any external Worship to God or not, we ought to depend upon such like united Rules of judging. Now all this conspires at once to make us sensible of the Existence of Bodies ; for 1. at all Times, constantly, and from my Birth, I perceive by my Senses a Thousand and a Thousand different Bodies ; and in this Variety I can distinguish the same Bodies.

Bodies. 2. I find in my self a necessary Inclination to believe what the constant Information of my different Senses tell me concerning the Existence of Bodies. This Inclination has nothing in it foreign to my Nature, I received it with my Life; therefore must have received it from the Author of Nature. 3. The Author of Nature is equally good and wise; of this the Idea of God convinces me. Being equally good and wise, would he permit me to deceive my self in judging both upon the constant Information of my Senses, and upon a necessary and natural Inclination which he has planted in my Soul, and also upon the Idea which I have of his Wisdom and Goodness, in a Matter of Consequence, wherein I do nothing contrary to Reason, but am rather authorized by it? My Reason tells me that God does not permit it, at least without derogating by a Miracle from the Laws of his ordinary Providence, one of which unavoidably leads me to judge that there are Bodies.

Therefore without the Aid of Revelation I know the Existence of Bodies.

Eud. But you who doubt so little of the Existence of Bodies, are you well assured that your own is not a Phantom?

Arist. If my Body is only a Phantom, I owe no external Worship to God: But I owe him an external Worship; every Thing tells me so, my Reason cannot doubt it; therefore my Body is no Phantom. Seeing I am a reasonable Be-

ing, I ought to be capable of discerning whether I owe my Creator an external Worship or not; but I cannot discern it without knowing whether I have a Body, or not. All the soundest Rules of Truth oblige me not to question whether I have a Body; therefore, &c.

Eud. Your Reasonings are solid.

Arist. They ought to be so; I have drawn them from your Writings.

Eud. You are too forward in praising, *Aristus*. A true Taste of Truth rarely praises.

Arist. A true Relish of Truth pays to Merit the Tribute that is due to it, and Praise is the natural Tribute of Merit.

Eud. There needs no extraordinary Merit to find out Reasons for judging that there are sensible Bodies before our Eyes. But is there a Species of imperceptible Body more refined than the Air itself, and which after *M. Descartes*, we may call subtle Matter, and celestial Matter? Nothing is of greater Importance to Physicks; it is perhaps the most fertile Source of the Wonders of Nature. In order to discover this fertile Source, we must first have some Idea of this Air which we breathe.

Arist. The Air, *Eudoxus*, which we breathe, preserves and prolongs our Days; is it not very just then that we bestow some Moments upon enquiring into its Properties?

Eud. It certainly has surprizing Properties; and what appears to me yet more astonishing is, that the greatest Part of Mankind are sensible

ble of their Efficacy, without knowing them. Hardly do the Vulgar know there is such a Thing as Air, unless the Reality of it be manifested to their Senses by the Gugglings of a Bottle, caused evidently by the interrupted flowing of the Liquor, and the violent and alternate entering of the Air.

They call Air this transparent Liquid which surrounds us immediately, which the Face or Hand feels when one agitates it rapidly with the Hand only, or with a Fan, and which carries Coolness and Life into the Lungs by Respiration. This Liquid encompasses the whole Earth, since it is equally a Principle of Life for all Men every where. It is extended even above the Top of the highest Mountains; and its universal Extension is what we call the Atmosphere †.

The Atmosphere, tho' its Transparency renders its small Parts invisible, is blue in itself; for 1. Lift up your Eyes towards Heaven in fair Weather, and it presents this Colour to your View on all Sides, which makes us give the Name of Sky-blue to that which resembles it most. 2. You would say that a Sky-blue were spread over the high Mountains, which one sees at a Distance through the Atmosphere. 3. In the Night, when the Air is without a Cloud, receive upon a Sheet of white Paper, but separated in two Places by an opaque

† See Notes on Conversation XXII and XXIII.

and perpendicular Piece of Pastboard, the Light of the Moon, and of a Candle; the Place enlightened by the Light of the Candle appears reddish; and that by the Light of the Moon appears blue &c. Is not this because the first has passed through a little Air, and the other by passing through much, the Colour of which is blue, is in some sort dyed with it? It is true, the Air which is near us does not appear blue, but that is because in a small Space there are not Parts enough coloured in such Sort, as to make any sensible Impression. Thus while a Glass of Wine appears to be of a lively red, and such as invites us to drink, one Drop only of the same Wine has but a weak Colour; because in the full Glass there is a Number of Parts livelily coloured, the Impression of which is united in the Eye, while there are only a few in the Part that is separated; and if the Wine contained in the Glass is but faintly coloured, the separated Drop appears as clear as Water.

Arist. What then is the Nature of this coloured Air?

Eud. The Air is a Body whose Parts are very fine, short, agitated, less indeed than those of Fire, but more than those of Water, ramose, flexible, having a Stiffness and a Springiness like those of Cotton. 1. The Air is a Body; for it makes itself to be felt, it cools, and has

Extension. Fasten a burning Coal to the Bottom of a Vessel turned upside down perpendicularly; plunge the Vessel into Water; the Coal is sunk without being extinguished; but for what Reason? Because the Air having no Vent, and presenting to the Surface of the Water the equal and smooth Surface of its own Extension, with the same Resistance in all the Parts of its Surface, hinders the Water from penetrating, and approaching the Coal. 2. The Air has Parts very fine and short; it flows through imperceptible Pores, is moved, gives Place, and is divided, without any sensible Resistance, in our passing from one Place to another. 3. The Air has Parts agitated; it dries Linnen: How is that done? Why by loosening the small Parts of the Liquor, which it cannot do but by the Agitation of its own Parts. 4. The Parts of the Air are less agitated than those of Fire, because the Fire dries Linnen much quicker. But the Particles of the Air are both more agitated and more minute than those of Water; accordingly the Air conveys Odours more effectually, neither does it freeze, while Water is turned into Ice. Finally, the Parts of the Air, though they are very fine, are nevertheless branchy, flexible, and elastic, since the Air is compressed and dilated like Cotton.

Arist. Has the Air, say you, its Spring?

Eud. A Body which is contracted and bent by the Action of some foreign Force, and which is dilated and unbent as of it self, has
its

its Spring or elastic Virtue: Now the Air is contracted and dilated, bent and unbent, after this Manner: For 1. press an ordinary Foot-ball on all Sides: It is compressed, and cannot be so without the Contraction and bending of the internal Air. Forbear that Pressure, and the Foot-ball will be extended: Why? Because the internal Air being set at Liberty, it is dilated and unbent. 2. By Means of a small compressing Pump and some Suckers, they make the Air enter at several Times into the Cavity or Chamber of a sort of Fusée, which they call a Wind-gun. The Suckers being shut up by the Effort which the Air makes to get out, retain it there on one Hand; a moveable and cylindrical Key retains it on the other; and there you may compress, bend and contract it twenty, fifty, nay a hundred Times more, if you will, than it was contracted without. Run a Bullet into the Barrel of this philosophical Fusée, and turn the Key: The Air being freed, suddenly issues out, and violently drives the Bullet before it: Take Care not to stand before the Mouth of the Fusée, for being pierced with the Stroke, you would take the Effect of the Air for that of Gunpowder, though too late. The Bullet will pierce a Plank through and through. Let us try the Experiment. Whence Proceeds this surprizing Effect, if not from the successive Contraction and Dilatation of the Air? Therefore the Air has its Spring. Further, I say it has

The Existence of subtile Matter. 27

has Weight. One Day or other we shall see a Proof of this in its marvellous Effects. Let us return to the subtile Matter; or rather let us defer it till to Morrow.



CONVERSATION III.

Upon the Existence of the subtile Matter.

Arist. I Do not well know, *Eudoxus*, how you will convince me that there is subtile Matter in the World. I have seen some old Philosophers, nay Professors of Philosophy, who are equally to be respected both for their Age and Dignity, declaim vehemently against this subtile Matter. If you should hear them in their Transports, it is nothing but the Effect of an Imagination capable of overturning both Physicks and Morality. They produce a Reason for it which you would not easily conjecture; that is, that they cannot see this subtile Matter.

Eud. The Reason is wonderful! They are of such an Age, that they can scarcely see the biggest Objects at their Feet; and yet in a gay humour they annihilate the smallest, because they do not see it. I am much afraid, lest those antient Enemies to a subtile Matter, far from

from annihilating it, should become annihilated themselves in our Eyes, through the want of a subtile Matter to warm that Blood which old Age has froze in their Veins.

Arist. But pray, *Eudoxus*, what do you understand by subtile Matter? Is it that globulous Matter, those imperceptible hard and round Bodies, whose Discovery and Original are equally ascribed to *M. Descartes*? Or that Matter which is still more minute and more agitated, which according to the Fancy of our modern Philosophers, changes its Figure more easily than *Proteus*?

Eud. I understand here in general by subtile Matter †, a Matter finer than the Air which we breath; Matter very minute, and which being continually agitated after a Thousand and a Thousand different Ways, and preserved in its Agitation by that of the Stars and the Sun, cannot fail of taking and having in its Corpuscles, a Thousand and a Thousand different Figures, triangular, square, spherical, &c.

Arist. But how do you prove the Existence of a Matter, which you seem to believe as ancient as the World itself, and which yet appears new to many of the Learned.

Eud. To prove this, I observe, and shall make others observe, a Fact in a Machine, which they sometimes call *Boyle's Machine*, sometimes an Air-Pump, or *Machina Vacui*.

† See the Notes upon Conversation V.

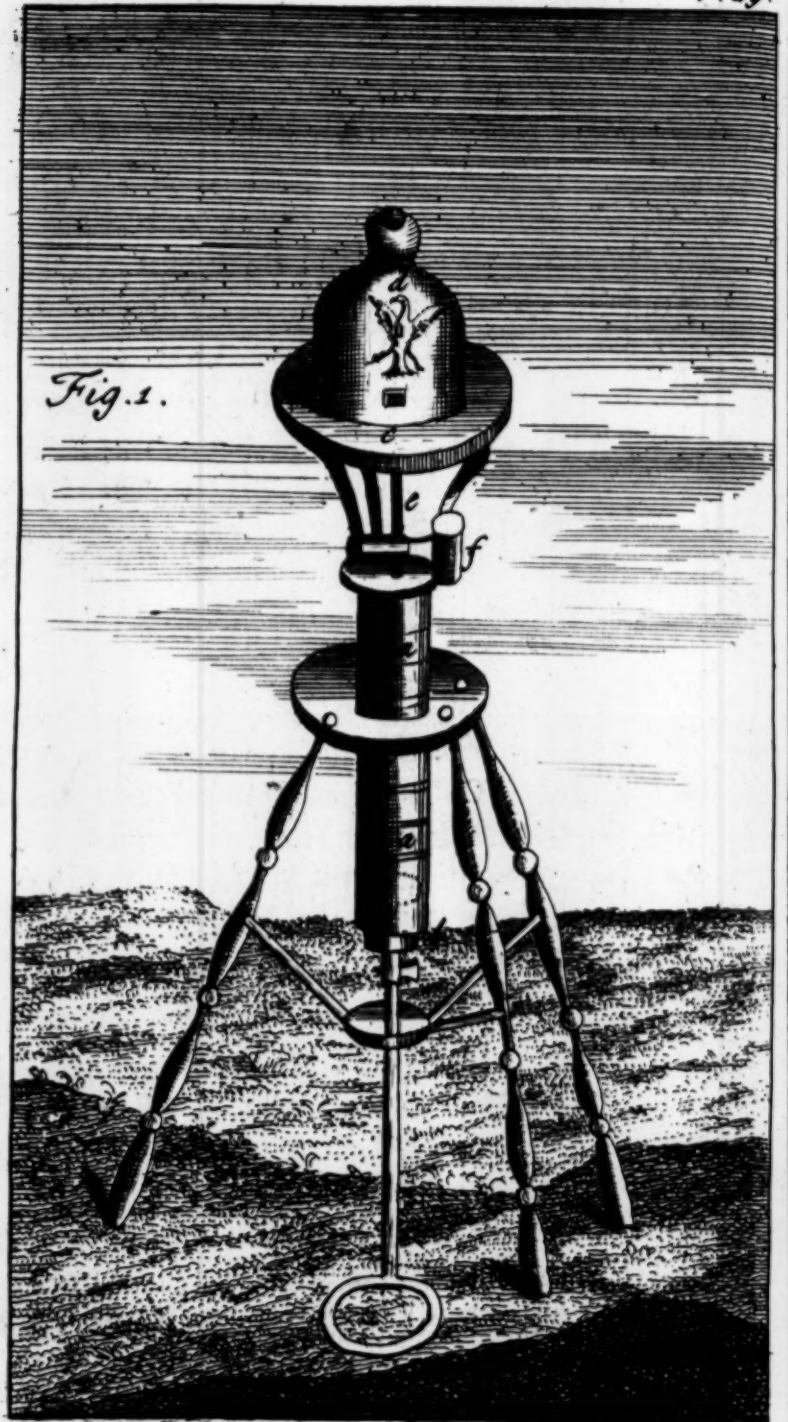
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Vacui.

Pray



P. 29.

The Existence of subtile Matter. 29

Pray observe mine, *Fig. 1.* It is composed, as you see, of a Pump, or hollow Cylinder (*a*); a Piston, or solid Cylinder (*b*), which ascends or descends at Pleasure; a Copper-Plate (*c*), bored through the Middle, upon which I place a Vessel of Crystal (*d*), made almost in Form of a Bell, and which is called the Receiver; a Pipe (*e*), which communicates with the Barrel and the Receiver by the Hole in the Plate; a cylindrical and moveable Key (*f*), which divides at right Angles like the Screw of a Cock, and shuts or opens at Pleasure the Communication of the Barrel and Receiver. The Key, when it shuts the Communication, has in its inferior Surface a Groove, or sort of small Channel, by which the Air may issue out of the Barrel without entering into the Receiver.

If I open the Communication, and draw the Piston downward, you will hear the whizzing of a liquid Matter, which passes with an accelerated Swiftneſs from a larger Space into a narrower, from the Receiver into the Barrel, by the Hole of the Plate. I raise the Piston, after having shut the Hole of Communication; the pumped Matter issues out impetuously by the Grooves of the Key: I continue pumping at several Times. The liquid Matter still issues out with a Noise, assisting my Endeavour to draw the Piston; but at last the Noise ceases, and my Effort is no longer seconded.

Pump

30 CONVERSATION III.

Pump an hundred Times without suffering the pumped Matter to enter again into the Receiver: The Receiver never fails to be full of Matter; for it is full of Light, and Light is a Body, since a Light too lively hurts the Eyes, and it is only one Body that disorders, touches and hurts another: Now this Matter which always fills the Receiver, is different from that which is pumped out. That which is pumped out, cools, and preserves Life. Animals die in the other; this Goldfinch, in which I take so much Pleasure, would presently lose therein both its Gaiety and Life, as an hundred little Sparrows have already done. The first whistles in going out; and my Watch strikes in it what Hour you please; the other makes no Noise, and the Watch is never heard in it. The first secends the Descent of the Piston, the other does not in the least facilitate it: The first neither penetrates Glass, nor Crystal; for otherwise being driven out of the Pump by the Groove, it would return in making a Circuit, pass through the Receiver, enter into it again, and always produce the same Effect; as Air driven out of a Chimney by the Flame, always returns with the same Whistling through the Cracks of the Doors or Windows: The other penetrates the Receiver without Resistance, since it succeeds the former, and transmits Light to our Eyes. The first then must be more gross, and that is Air; this other must be finer, and is the subtile Matter. Therefore there is
subtile

The Existence of subtile Matter. 31

subtile Matter, which was the Thing to be proved.

There is, I say, a subtile Matter, and this subtile Matter is as old as the Universe, if there is in the Air, which we breath, Matter finer than Air itself: Now there is in the Air Matter finer than the Air itself; for Matter which penetrates Glass and Crystal, is finer Matter than Air itself; the Air which carries Life into our Lungs neither penetrates Glass nor Crystal, since Animals die for want of Air in a large Vessel of Glass or Crystal: But there is in the Air a Matter which penetrates Glass and Crystal; Light certainly penetrates both the one and the other, since it makes us see coloured Objects through both; and its Rays passing through a Prism present to our Eyes the Colours of the Rainbow, and paint a Wall with the most beautiful Colours: Now Light is Matter diffused in the Air, it is a Body; in short, Light touches, agitates and hurts the Eyes; and what touches, agitates, and wounds a Body, is Body: *Lucretius* speaks like a Philosopher, when he says:

Tangere enim & tangi, nisi corpus, nulla potest res.

Body alone can touch, and touches only Body: Therefore there is a subtile Matter.

But further, is there not a Matter more delicate than Air, a subtile Matter, which in Time of Heats being sensible, if I may thus speak,

32 CONVERSATION III.

speak, of the new Degrees of Heat, pierces the Glas of the Thermometer, and therein makes the Spirit of Wine ferment and ascend, in order to let us see with the Eye those new Degrees of Heat which we feel? And must not some Matter of this Species insinuate itself into the Bosom of the Earth by a Thousand imperceptible Channels, in order to give by their Motion to divers Elements that Configuration, Arrangement and Texture, which constitute precious Stones, Silver and Gold? Is it not a subtile Matter, which directs, agitates and animates the Loadstone, and issues out of its Substance, in order to encompass it with a Vortex of Filings of Iron; and makes Iron or Steel court it or fly from it, while precious Stones, Gold or Silver make no Impression thereon? Is it not this same Matter which by imperceptible Passages searches out, corrodes, undermines, and consumes the internal Parts of hard Bodies, and reduces to Dust, Stones and the most stately Edifices? Is it not that which by its Agitation causes the Fermentations, the Fluidity of the Blood and Humours, and renders the Substance of the Brain more soft, flexible, and fit for producing new Ideas.

Arist. That is to say, subtile Matter works Miracles in the Sight of those who admire them, while they do not acknowledge it. It enlightens them, yet they perceive it not; its Light discovers the most secret Mysteries, and yet does not make itself known; it remains in
 Darknes,

The Existence of subtile Matter. 33

Darkness, while it spreads a Light over all; it gives Vivacity and Penetration to the Mind, yet the Mind uses them maliciously against it: For you may daily hear some of your new Philosophers jesting upon subtile Matter. It is the Source of Riches, and yet is rejected; it revives old Age, which would gladly reduce it to nothing, or dissipate it, if by its prodigious Subtlety it did not escape the Eyes of its Enemies. (By making Men happy, it makes them ungrateful).

Eud. I apprehend, *Aristus*, that the very Idea of a subtile Matter awakens your good Humour. Perhaps the subtile Matter has a greater Share therein than you think of; the lively, but moderate Agitation, which it produces in your Blood and the Fibres of your Brain, serves to dissipate any cloudy Humours, and give you pleasing Ideas. You jest, you laugh at my Sentiments concerning a subtile Matter; I hope our Conversations will convince you of its Reality, and that this subtile Matter has made you a Man of Wit, without making you an Ingrate.

Arist. I believe your Sentiment in the Main is solid, *Eudoxus*; I am for a subtile Matter. It cheers my Mind; I love to see it circulate at your Pleasure through the whole Universe, and work Wonders every where. Nay its Smallness gives me no Uneasiness neither, since we have seen Animals seven and twenty Millions of Times less than a Mite. But how came

34 CONVERSATION III.

Aristotle, whom they call the Genius of Nature, not in the least to perceive this fertile Source of Wonders?

Eud. Though *Aristotle* did not perceive it, it was however not at all the less real: He had no Notion of the Circulation of the Blood, which flowed in his Veins; yet the Blood has never ceased to circulate in all Men from the very first even down to us, passing with a prodigious Rapidity from the Heart to the Extremities of the Body, and returning with the same Velocity from the Extremities to the Heart, as we shall see one Day or other. But read *Aristotle*; you understand the *Greek*, tho' unknown to many of *Aristotle's* Enemies; in a hundred Places he speaks of an ethereal Matter, of a Fire universally diffused, in the Air, and above the Air. This Fire, this ethereal Matter, is it not the subtile Matter, of which they will have *M. Descartes* to have been the first Inventor?

Arist. Though a subtile Matter had not obtained the united Suffrages of *Aristotle* and *Descartes*, yet should I voluntarily yield to your Reasoning: Notwithstanding your Reasons suppose Bodies to have Pores, that they are pierc'd through with a Thousand and Thousand Holes; I should be glad to see those Pores, those imperceptible Holes, as clearly as I perceive the subtile Matter, and then I should be satisfied. I have seen some Persons who have been incredulous about these imperceptible Pores.

Eud.

Upon the Porosity of Bodies. 35

Eud. Well, we shall endeavour to satisfy you upon this Head in our next Conversation.



CONVERSATION IV.

Upon the Porosity of Bodies.

Arist. **W**HEN one sees the whole Universe overflowed with a subtile Matter, and is convinced that it is, as it were, the Soul of it, we must of Necessity allow it a free Passage in an extreme Porosity, in order to its spreading its Influence universally. I dare say, *Eudoxus*, that you see clearly, even in this subtile Matter every Particle, as it were, bored and pierced in a hundred Million of Places at least. But to speak freely, is it probable that all Bodies have their Pores?

Eud. It is not in the least probable that all imperceptible Bodies have them; neither my Eyes nor my Reason see them in the subtile Matter. The Particles of such like Corpuscles have so little Consistence, and are so minute, that the least Force ought, I imagine, to unite them immediately. But as the Particles of all sensible Bodies have more Solidity, and different Figures, as round, square, &c. it is probable

36 CONVERSATION IV.

bable that they have Interstices or Pores. What say I, probable? It is a certain Fact, which Reason and Experience jointly teach us.

Bodies cannot be compressed without Pores; Compression is occasioned only by the Approach of the Particles, and their Approach supposes that they were separated by Interstices, which are otherwise called Pores. Experience sufficiently shews that all sensible Bodies are compressed, even the most solid. Ivory does it remarkably. Let fall a Billiard Ball from a certain Height upon a Plane of Marble covered over with a light Lay of Tallow; you will see in the Tallow a round Figure, pretty large, which could not have been made but by a considerable flattening of the Ball. Therefore all sensible Bodies have their Pores. Why does Water weigh fourteen Times less than an equal sensible Portion of Quicksilver? Because Water possesses no more than the fourteenth Part of the Space which it seems to do; so many Interstices are there in it.

What Species of Body is there, that has them not? 'Tis evident that Crystals, Rubies, and Diamonds have them; since they are transparent, and afford a Thousand free Passages to the Light, which is a Body that often dazzles and hurts the Eyes. Why does a Ball of Glass, hollow and full of Light, move as easily upon an horizontal Plane, as if it contained no other Matter than its own? Because the luminous Matter, of which it is full, issues out freely,

freely, and other Matter of the same Sort enters with the same Freedom through the Pores of the Glass; otherwise the Sphere would make as great a Resistance as if it were full of Mercury, since its Resistance would be according to the Quantity of Matter which it contained. Is not your Body all over full of Pores? There is not one Part, wherein Sweat does not find some Passage in a Crisis, or an excessive Heat: And why does it grow lean through your Intense studying of Philosophy? Because its Substance, which the natural Heat puts into a continual Agitation, is exhaled by Transpiration, without your taking any Care to recruit it. Some Philosophers who have been so curious as to weigh both their own Bodies, and the Nourishment which they took, and the Superfluity that passed off without being changed into Juice, have discovered that the greatest Part of our Aliment must be dissipated by Ways imperceptible.

Arist. The Light, which comes to my Eyes through Glasses and precious Stones, discovers Pores to me therein; that Transpiration, which according to you dries me up, obliges me to acknowledge them in my self, beyond what I am able to imagine. But hard and opaque Bodies, Oak for Example, Metals which are the most compact Bodies, Iron, Silver and Gold, should they be also made by Nature to give Access to the subtile Matter?

38 CONVERSATION IV.

Eud. The subtile Matter, which since the Origin of the World has been preserved only by Agitation, ought, no doubt, in labouring to form those Bodies, to have provided therein free Passages for necessary Occasions. Would you believe it, *Aristus*? Oak has at least twenty Times more Pores, and void Spaces in it, than it has of its own Matter. In short, the apparent Bulk, the Mass of Oak weighs twenty Times less than an equal Bulk of Gold. For Water weighs nineteen Times less than Gold, and Oak weighs less than Water, since it floats upon it. Metals dissolved by Heat, let us see sufficiently that they have Pores open, and always ready to receive Corpuscles of Fire, their Destroyers and Enemies; but you must have Facts more surprizing; then observe them.

1. Lime and Orpiment digested ten or eleven Hours in Water, over a Sand Heat, afford a clear Liquor. Write with Vinegar impregnated with Salt of Lead, and the Writing does not appear; but the former Liquor passing through an entire Book, you will be able to read that invisible Writing. And this is sympathetick Ink ||.

2. Shut up in Boxes of any Sort of Metal you please, some Tin or Silver: The sulphureous Exhalation ^h of the *Boulogne* Stone, newly calcined, finds Access to it, it dyes the Tin with

|| Lemery, p. 390.

^h Mem. de l'Acad. p. 142. 1709.

the Colour of Silver, and Silver with that of Gold. How does the Exhalation pass through?

M. Hombergh, an expert Chymist of the Academy of Sciences, made Salts pass calmly through Iron and Silver before your Eyes. One may believe itⁱ. A Salt extracted from a Mixture of quick Lime, distilled Vinegar, Saltpeter, Sea Salt, and common Sulphur, melts in an Iron crucible over a strong Fire, and quietly penetrates the Iron, as Water passes through brown Paper, without disordering any Part, or leaving any Trace of its Passage. One Part of Lime drawn from a Solution of fine Silver, two Parts of corrosive Sublimate, and three of crude Antimony, reduced to Powder, mixed exactly, and distilled over a Sand Heat, afford a bituminous metalline Matter, which melts like Wax; and being melted upon a Plate of Silver about half a Line thick, is imbibed into this precious Metal, and penetrates it through and through without causing the least Alteration in it. Wherefore Nature, which is more wonderful still in what she conceals from our Senses, than in sensible Objects, must have disposed in Iron and Silver a prodigious Number of Pores, all communicating with one another. Gold has its own Pores, as well as Silver; for Spirit of Sea Salt dissolves Gold, and *Aqua Regia*, composed of Spirit of Salt and Spirit of Nitre, reduces Gold into a Liquor.

ⁱ Mem. de l'Acad. 1713. p. 308.

Without the Interstices in the Gold, could this Dissolvent find Access into the Texture of this Metal, or could it eat into it?

Arist. The Experiments and Labours of the Academy have certainly given us a great Light into several very obscure Things. Your Reasonings, and the Experiments of *M. Hombergh*, discover to me by what Ways the subtile Matter can, in some Sort, animate the Earth. Those secret Ways, those imperceptible Routs, have probably different Figures, and are of various Bigness in divers Bodies; the various Texture, which makes different Bodies, ought to cause this Variety in the Pores: But I should be glad to have some Experiments capable of convincing me beyond all Contradiction. Experiments which strike the Senses, often confirm our staggering Reason.

Eud. Experience in this Case still agrees with Reason. Why is Spirit of Nitre a proper Dissolvent of Silver and not of Gold, and Spirit of Sea Salt the proper Dissolvent of Gold, and not of Silver? Why does *Aqua Regia*, compounded of Spirit of Salt, and Spirit of Nitre, reduce Gold into a Liquor, without dissolving Silver; while *Aqua Fortis*, in which Spirit of Nitre is predominant, reduces Silver into a Liquor, without dissolving Gold? The different Porosity of Gold and Silver probably occasion those different Effects. Since Gold weighs much more than Silver, probably the Pores of Gold are much straiter. Whence the

the Points of Spirit of Salt being probably finer than those of Spirit of Nitre, find themselves too much at Liberty in the Pores of Silver, and make no Impression upon it; but sliding with some Difficulty, notwithstanding their Smallness, into those of Gold, they produce therein the Effect of a Wedge, by dividing and dissipating the solid Parts. On the contrary, the Points of Spirit of Nitre being probably thicker than those of Sea Salt, penetrate into the Pores of Silver with Difficulty, and therein do the Business of a Wedge, by separating and dissipating the solid Parts: But not being able to run into those of Gold, they make no Impression upon it; however being mixed with Spirit of Sea Salt in the *Aqua Regia*, they find Access into the Gold, corrode and demolish it, because the Spirit of Salt makes them fine enough to gain with some Effort a Passage into the Interstices of the Gold. Thus Water, which passes freely between the Arches of a Bridge, does it no Harm; but should it meet with any Obstacles, it overturns all. It sometimes happens that *Aqua Fortis*, too pure, and too subtile, is a Sort of *Aqua Regia*, that dissipates Gold and spares Silver: Pour upon it a certain Quantity of common Water, and it will dissipate Silver, and spare Gold. Whence then does this proceed, but from the Inequality of the Pores^k?

* Hist. de l'Acad p. 374.

Wine and Water discover to us, as well as Spirit of Salt and of Nitre, a Difference in the Pores; For Wine, which is filtred and insinuated into the Substance of several Bodies, does not always pass through where Water passes. If you suspect any Mixture of Water in Wine, pour the Liquor into a Vessel made of Ivy; that Water which might have deceived you under the Appearance of Wine, parts from it, goes off, and distills Drop by Drop; the Wine remains at the Bottom of the Vessel, and the Taste finds nothing there but pure Wine.

Arist. Well, I see plainly, you will not have the Water, which takes or seems to take the Colour of Wine, take also its Nature. You chuse rather to conceal it in the Pores or Interstices of the Wine.

Eud. If 'tis possible to separate Water from Wine ten Days after they have been mixed, it is evident that Water does not assume the Nature of Wine in the Mixture: But this may be done, and Father *Maignan* of the Order of *Minims* has done it*.
“ I mixed, says he, with one Part of very
“ clear Well-water, two Pints of old Wine,
“ pure and of a strong red Colour. I let the
“ Mixture alone for about ten Days and ten
“ Nights in a Vessel, very little concave, and
“ whose Mouth was large, waiting for a Degree
“ of cold, fit to freeze the Water without

* T. I. p. 332.

“ freezing

“ freezing the Wine. A North-Wind produced this Effect in the Night. In the Morning I found the Water frozen upon the Window without. I bowed down the Vessel. The Water remained still immoveable, but immediately almost the Wine distilled. You might have seen the Drops of this Liquor filter through the Water, pass successively from Interstices to Interstices, and run into the Vessel which I had set under it. All the Wine quitted the Pores of the frozen Water. It became wholly whitish, and was pierced through with Thousands of small Holes, like a sort of Fringe. Finally, when the Ice was melted, there was nothing to be seen in the Vessel, but very clean Water, without any Appearance of Wine.

Arist. I am equally convinced of the Porosity of Bodies, and of the Variety of their Interstices; but fear least my restless Imagination should seduce my Reason, when my Eyes do not discern the Objects; pray let us try to discover the Pores with a Microscope. Whatever strikes the Eyes, makes a deeper Impression upon the Mind, than any Thing related to us by the Learned: *Horace* very well observes †.

*Segnius irritant animos demissa per aurem,
Quàm quæ sunt oculis subjecta fidelibus. —*

† *Ars Poet.* v. 180.

Eud. Here is my Microscope, you may see Pores, in some Sort, invifible. You will fee fome at leaft in a Coal; there they are difpofed in Order, and very numerous. A certain Philofopher¹ fays, that he has feen them with a Microscope, and counted to the Number of 150 in one Row, the eighteenth Part of an Inch long; now according to the Calculation of that Author, a Coal of an Inch Diameter ought to have in it more than five Millions. Obferve then thefe Pores, and fhew them to your incredulous Philofophers, if their Eyes are yet in a Condition to behold Objects magnified, and fuch as are twenty or thirty Millions of Times bigger than in their natural State.

Arift. I am fenfible there are Pores, *Eudoxus*; but are thofe Pores empty or not? I fee nothing in them but Darknefs; for my Part I can difcern no fubtile Matter.

Eud. To Morrow I will tell you my Sentiments on this Head; in the mean Time confider of it your felf; we will endeavour to difcern if there be really any Vacuum in Nature, or if it be any other than that, which according to the Language of the Vulgar, is often found in the Bottle, the Purfe, or the Head.

¹ *M. Hook.* Journal des ſçavans, XXII. Dec. 1666. p. 738.



CONVERSATION V.

Concerning a Vacuum.

Eud. **W**ELL, *Aristus*, since our last Conversation has your Mind taken any Flight in your profound Meditations upon a *Vacuum*? Has it penetrated this *Vacuum*, this immense Nothing, which they place immediately upon the Surface of the World? Has it run over those Spaces where the Sight is lost, and where Imagination alone wanders at Pleasure?

Arist. My Mind, *Eudoxus*, has made no useless Journey into your imaginary Spaces; it never went out of this World, which however ought to have its proper Bounds, though the divine Power has none; it remained within my Closet, employed about those Pores, those Species of small Vacuities with which Bodies are bestrewed. And seeing nothing there with the Microscope, no not so much as the least Trace of a subtile Matter, it asked itself what is a *Vacuum*? Is it possible? Does it exist? And I think I have hit upon the Truth.

Eud. Your Mind is methodical in its Enquiries; but what is a *Vacuum*?

Arist.

Arist. A *Vacuum* is properly a Surface capable of containing a Body, without containing however any one at all.

Eud. This is the Idea I have of a *Vacuum*. But is a *Vacuum* possible?

Arist. Can Reason doubt it, *Eudoxus*? What ever implies no Contradiction is possible; a *Vacuum* implies no Contradiction; for what Contradiction is there in a Surface proper for containing a Body, and which yet contains none at all? These Terms no Way destroy one another: Therefore a *Vacuum* is possible.

In a Word, should God at once annihilate this Air, and all the Matter wherewith we are surrounded in this Closet, without making any Change in the Situation of the Closet, or in the Bodies that surround it, there would be a *Vacuum*, and one might say that then we should find our selves immediately under Nothing: Now this Supposition has nothing in it impossible, nothing contradictory, nothing that is above the Power of a God, who stands in Need of nothing, who freely preserves the Bodies which he does preserve, who can annihilate some, without others, since they are so many distinct Substances, that he can work a Change in them, or not; therefore, &c.

Eud. Neither *M. Descartes*, nor *M. Robault*, nor *M. Regis*, two of the most celebrated *Cartesians*, were of your Opinion.

Arist. I know it, but I know also that in this Matter their Understanding was the Dupe of their

their Imagination; their Imagination made them see Extension in all the intermediate Spaces of Bodies, and this Extension they took for a real Extension, for a Portion of Matter; but they took the Phantom for the Reality. Let us carry our Imagination as far as we please beyond 6000 Years, or thereabouts, which are past since the Creation of the World, our Imagination still supposes an Extension; but in that Extension is there any Solidity? None at all; otherwise the World would be eternal. Our Imagination feeds itself with corporeal Images; the Sight of Bodies fills it with the Image of Extension. Hence wherever our Imagination is carried, the Image of Extension accompanies it; but this is only an imaginary Extension, which has nothing of Body in it, and which vanishes before the Eyes of Reason.

Eud. Thus far I agree with you in your Sentiments about a *Vacuum*. But is there any *Vacuum* in the Universe? I believe there is no such Thing; why? Because there is no Proof of its Existence, and I see nothing more useless than a *Vacuum* for producing the Wonders of Nature.

Arist. For my Part, I own freely that since I have seen with your Microscope Pores in a prodigious Number, and so many Sorts of *Vacuums*, I find it difficult not to acknowledge at least some small real *Vacuums* with *Gassendus*, *Lucretius*, and *Epicurus*.

Eud.

Eud. You are then something of an *Epicurean*?

Arist. Yes, but then it is only in a Point, wherein one may be so with Honour. If I place my fleeting Happiness in Pleasure, it is only in the Pleasure of learning the Truth from your Mouth. I am also surprized that you are not something of an *Epicurean* your self: For, in a Word, those Pores so numerous and almost infinitely small, which you have made me see in sensible Bodies, have a great Appearance of being perfectly void; they are so in the Judgment of the Eyes; are they not so in the Judgment of Reason? What is it that fills them?

Eud. The subtile Matter ‡.

Arist.

“ ‡ Since the Resistance of a fluid Medium arises chiefly from
 “ its Density, it from thence necessarily follows, that where there
 “ is no sensible Resistance of the Medium, there the Medium must
 “ have no sensible Density; and therefore since in the Heavens the
 “ Comets suffer no sensible Resistance, but exert their Motions with
 “ the greatest Freedom, as if they were in a perfect Void, or Va-
 “ cuum, there likewise the Density of the Medium must be the
 “ least that can be, or next to nothing. And who knows but the
 “ Medium in the Heavens may be so rare and fine, that if you
 “ except the Planets and their Atmospheres, the Matter which is
 “ diffused through all the rest of the Planetary Region, or our so-
 “ lar System, may not be so much as that which is contained in an
 “ Inch of our common Air. And this is demonstrated to be possi-
 “ ble in Keil's Physical Lectures. Keil's Phys. p. 202.

“ Liquors which differ not much in Density, as Water, Spirit
 “ of Wine, Spirit of Turpentine, hot Oil differ not much in
 “ Resistance. Water is thirteen or fourteen Times lighter than
 “ Quicksilver, and by Consequence thirteen or fourteen Times
 “ rarer; and its Resistance is less than that of Quicksilver in the
 “ same Proportion, or thereabouts, as I have found by Experi-
 “ ments made with Pendulums. The open Air in which we
 “ breathe

Concerning a Vacuum. 49

Arist. The subtile Matter! But the small Particles of subtile Matter have different Figures, round, square, &c. How are those different

breathe is eight or nine hundred Times lighter than Water, and by Consequence eight or nine hundred Times rarer, and accordingly its Resistance is less than that of Water in the same Proportion, or thereabouts, as I have also found by Experiments made with Pendulums. And in thinner Air the Resistance is still less, and at length by rarifying the Air, becomes insensible. For small Feathers falling in the open Air meet with great Resistance, but in a tall Glass well emptied of Air, they fall as fast as Lead or Gold, as I have seen tried several Times. Whence the Resistance seems still to decrease in Proportion to the Density of the Fluid. For I do not find by any Experiments, that Bodies moving in Quicksilver, Water or Air, meet with any other sensible Resistance, than what arises from the Density and Tenacity of those sensible Fluids, as they would do if the Pores of those Fluids, and all other Spaces, were filled with a dense and subtile Fluid. Now if the Resistance in a Vessel well emptied of Air, was but an hundred Times less than in the open Air, it would be about a Million of Times less than in Quicksilver. But it seems to be much less in such a Vessel, and still much less in the Heavens, at the Height of three or four hundred Miles from the Earth, or above. For Mr. Boyle has shewed that Air may be rarified above ten Thousand Times in Vessels of Glass, and the Heavens are much emptier of Air than any Vacuum we can make below. For since the Air is compressed by the Weight of the incumbent Atmosphere, and the Density of Air is proportional to the Force compressing it, it follows by Computation, that at the Height of about seven *English* Miles from the Earth, the Air is four Times rarer than at the Surface of the Earth; and at the Height of 14 Miles, it is sixteen Times rarer than at the Surface of the Earth, and at the Height of 21, 28, or 35 Miles, it is respectively 64, 256, or 1024 Times rarer, or thereabouts; and at the Height of 70, 140, 210 Miles, it is about 1000000, 1000000000000, or 1000000000000000000 Times rarer, and so on.

“ Heat promotes Fluidity very much by diminishing the Tenacity of Bodies. It makes many Bodies fluid which are not

50 CONVERSATION V.

ferent Figures matched so with the Figures of the Pores, that there does not remain in them the least *Vacuum*?

Eud. The subtile Matter being of an inconceivable Smallness, is extremely brittle, it is broken and bruised; it puts off and assumes all

“ fluid in Cold, and increases the Fluidity of tenacious Liquids,
 “ as of Oil, Balsam and Honey, and thereby decreases their Resistance. But it decreases not the Resistance of Water considerably, as it would do, if any considerable Part of the Resistance of Water arose from the Attrition or Tenacity of its Parts.
 “ And therefore the Resistance arises principally and almost entirely from the *Vis inertiae* of its Matter; and by Consequence, if the Heavens were as dense as Water, they would not have much less Resistance than Water; if as dense as Quicksilver, they would not have much less Resistance than Quicksilver; if absolutely dense, or full of Matter, without any *Vacuum*, let the Matter be never so subtile and fluid, they would have a greater Resistance than Quicksilver. A solid Globe in such a *Medium* would lose above half its Motion in moving three Times the Length of its Diameter; and a Globe not solid (such as are the Planets) would be retarded sooner. And therefore to make Way for the regular and lasting Motions of the Planets and Comets, it's necessary to empty the Heavens of all Matter, except perhaps some very thin Vapours, Steams or Effluvia, arising from the Atmospheres of the Earth, Planets and Comets, and from such an exceedingly rare ætherial *Medium* as is described in p. 323. *Newt. Opt.* A dense Fluid can be of no Use for explaining the Phænomena of Nature, the Motions of the Comets and Planets being better explained without it. It serves only to disturb and retard the Motions of those great Bodies, and make the Frame of Nature languish: And in the Pores of Bodies, it serves only to stop the vibrating Motions of their Parts, wherein their Heat and Activity consists. And as it is of no Use, and hinders the Operations of Nature, and makes her languish, so there is no Evidence for its Existence, and therefore it ought to be rejected. And if it be rejected, the Hypotheses that Light consists in Pressure or Motion propagated through such a *Medium*, are rejected with it”. *Newton's Opticks*, p. 341. &c.

Manner

Concerning a Vacuum. 51

Manner of Figures with an incredible Facility; and since Water takes immediately the Figure of a Vessel, round or square, you ought not to be surprized that the subtile Matter, whose Particles are infinitely more minute than those of Water, should accommodate itself perfectly to the Figure of the Pores, and exactly close up all those small *Vacuums* which you are so much afraid of seeing filled up.

Arist. There is a Necessity, *Eudoxus*, at what Rate soever, that you agree with me concerning those small *Vacuums*, or I will force you to acknowledge much greater ones in Nature.

Eud. By what Means will you force me to that?

Arist. By the Rarefaction and Condensation of Bodies. For how does Bread swell? How is Milk inflated so strangely when it comes to boil, unless its Particles are separated, removed from one another, and leave Interstices and *Vacuums*, much greater than those, which in Spite of me, you endeavour to fill up with your subtile Matter?

Eud. Rarefaction is an Action by which a Body augments its Bulk, without augmenting its Mass, or which makes the same Body precisely that appeared under a certain Bulk, to appear under a greater: But is it not sufficient for that, that the subtile Matter, or some fine Air, fill up, extend and enlarge the Pores, as *M. Descartes* believed after *Aristotle*? Bread

which is baked, swells, and is inflated; Milk which boils, is extended, ascends, and fills the Vessel; because the little Corpuscles of Fire, whose Agitation produces Heat, penetrate the Bread and Milk, insinuate themselves successively into their Pores, fill them up, and dilate them so much the more, as the Air which they meet with in them is extremely dilated; and thus your great Vacuities are filled up.

Arist. For to fill them, you dilate the Air strangely; but upon what Principle?

Eud. This is what Experience proves unanswerably, that Heat often gives the Air 200 Times more Extension than it had in its natural State.

Arist. If the Air is extended so prodigiously, it has then Vacuities, not small, but very large?

Eud. In Proportion as the Extremities of the Air are removed from one another in Rarefaction, the subtile Matter, the ætherial Matter, the æther, the celestial Matter, (give it what Name you please) fills up that Space which separates them. Therefore there is no Vacuity, neither small nor great.

Arist. Condensation at least supposes there are some.

Eud. What is Condensation? It is that Action which makes a Body diminish in Bulk, but not in Mass; or which makes the same Body seem to possess less Space than it did; without losing ought of its proper Matter. But Compression

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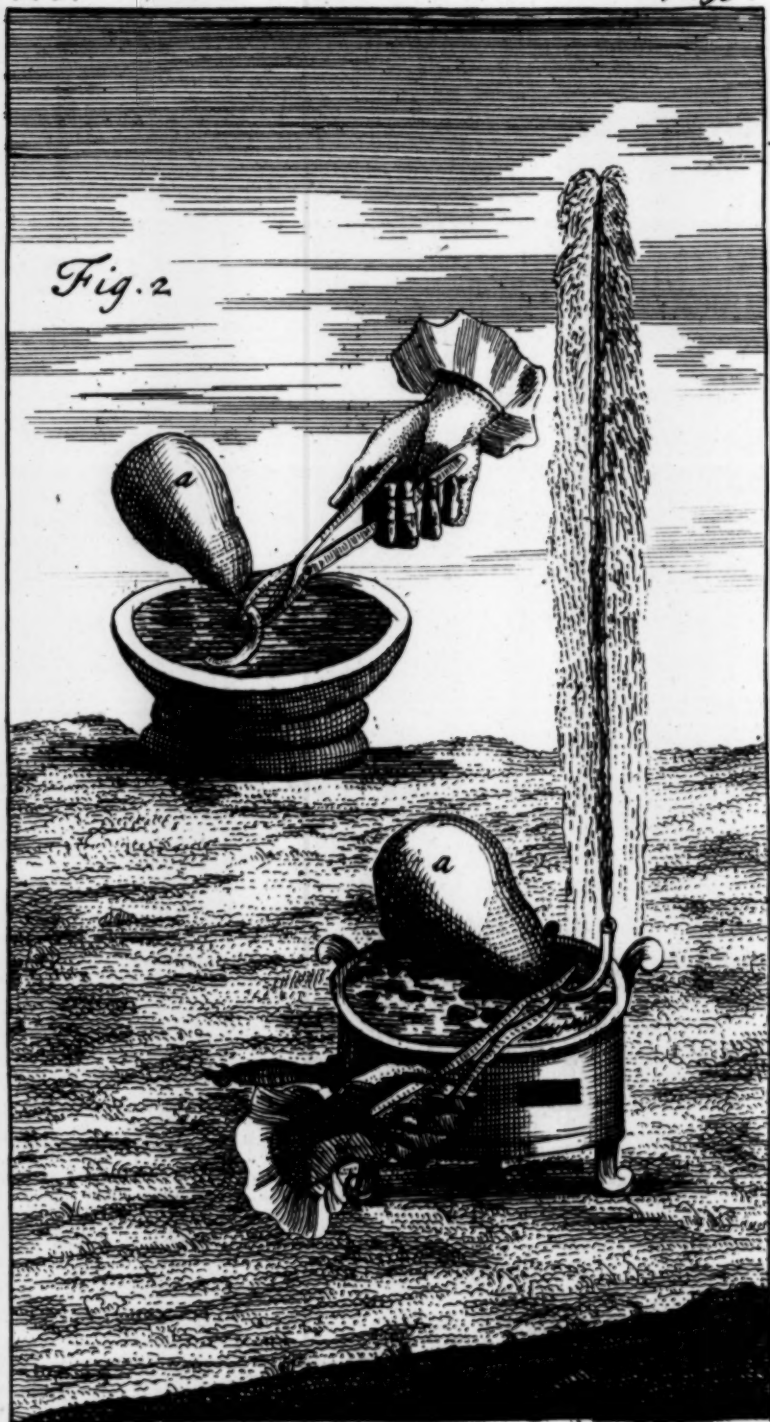
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Fig. 2



pression expels the Air or subtile Matter out of it; at the same Time the Extremities of the Pores approach one another: And thus a Body is condensed without a *Vacuum*.

Arist. Would you then explain without a *Vacuum* whatever is most surprizing in the Eolipile (a) Fig. 2?

Eud. The Eolipile is a sort of Vessel commonly made of Brass, in the Form of a Pear, having in the sharp End a small crooked Pipe. At first they set the Eolipile upon a quick Fire: The small Corpuscles of Fire, which insinuate themselves through the Pores of the Brass, dilate the internal Air by their violent Agitation, drive it out likewise, at least in Part, through the small Pipe, and take its Place. Then they take off the Eolipile from the Fire. You put the End of the little Pipe into Spirit of Wine. The Corpuscles of Fire that are most agitated seek some Vent; they find it in the Pores through which they entered, and then issue out. The dilated Air is cooled and contracted. Hence the Spirit of Wine being pushed forward by the external Air, and finding little Obstruction in the Content of the Vessel, where every Thing easily gives Way, flows into it proportionally as the Air is contracted, and as the Corpuscles of Fire issue out. Finally the Eolipile is set again upon a quick Fire. The Corpuscles of Fire penetrate it, insinuate themselves into the Pores of the dilated Liquor, and dilate them, by dilating the

54 CONVERSATION V.

Air which they encounter: The Liquor being dilated, and not finding Space enough in the Eolipile, is forced out abundantly through a very narrow Tube; it spouts out. Put a lighted Wax-Candle to it, and the Liquor catches Fire, and you behold with Astonishment a Spout of Fire that is darted into the Air, and its falling down again presents to the Eyes a burning Shower. This is the finest Effect of the Eolipile. What Appearance of a *Vacuum* do you see in it?

Arist. But what signifies it to fill every Thing with subtile Matter or imperceptible Bodies, if you must indispensably acknowledge Thousands of Interstices, or empty Passages in some Part or other? Now this you must do; and you go about it like a true Philosopher, that is to say, with a good Grace. For the Voice, with which this Room has resounded ever since our Conversation, ought to penetrate, and perhaps prove troublesome, in the next Room: How does it penetrate thither, if the Wall does not afford it a Thousand and a Thousand free Passages; and how are those Passages free, if they are not empty?

*Inter septa meant voces, & clausa domorum
Transvolitant —
Est igitur nimirum quod ratione sagaci
Quærimus, admixtum rebus quod inane vocamus.*

Thus

Thus *Lucretius* reasons. You will not hold it out against those Verses; the Taste of Truth has not made you lose the Taste of Poetry; you love Verses because they adorn the Truth.

Eud. The Truth is rarely found adorned by the Verses or elegant *Latin* of *Lucretius*. He might say as he pleased, that the Voice has no other Way but to make Vacuities in order to pass into the Neighbourhood: it is sufficient that the Air, which fills the Cracks and Pores of the Wall, communicates both with that which we breathe, and that of the adjacent Room. The Particles of this Air successively carry the Voice to another Place, and report our philosophical Disputes.

Arist. Fill a Glass Tube of 36 Inches, or an 100, if you please, with Quicksilver; turn it into a Vessel already full of Quicksilver; that in the Tube descends, and stops, as of itself and of Choice, at the Height of 27 or 28 Inches. In a Pump the Water ascends and follows the Piston to the Height of 32 Foot, or thereabouts; then it stops, and lets the Piston ascend alone as long as you will. What is it which fills up that Place which the Quicksilver and Piston leave? You would not have small Vacuities provided by Nature for letting the Voice pass; lo, here is one of more than 50 Inches; what say I? of 50 Foot at least.

Eud. The subtile Matter is always ready to succeed the Quicksilver. From the Time it

descends, the subtile Matter slips through the Pores of the Glass, and seizes the free Place in order to transmit the Light to our Eyes; and the same Reason determines it to get into the Place forsaken by the Piston, the Moment that the Water ceases to follow it.

Arist. I foresaw your Answer; and must indeed, soon or late, think as you do. You have nothing to do but speak. The subtile Matter comes from all Parts to second you, and leaves me nothing to reply.

Eud. You see, *Aristus*, as well as I, that a *Vacuum* is good for nothing. But the Motion of Bodies is a Source of curious and useful Events; Motion is the most fertile Property of Bodies. Motion carries Life into all the Parts of our Body; it makes the Light shine in our Eyes, fertilizes the Earth, covers it with Plants and Flowers, loads the Trees with Fruit, and makes the Sweetness and Charms of Spring succeed the Severities of Winter. Motion does in some Sort animate the World. Without Motion no more Commerce among Men, no more publick Shows, *Paris* would grow dull, every Thing languish, and the Universe become a formless Chaos. But Motion, that is so necessary and productive of Wonders, has its Essence, Properties and Rules: Without knowing them, we can know little of Nature; Nature is unveiled, whenever we know them. Let us meditate upon them for some Time, and whenever you please we will communicate
our

Upon the Nature of Motion. 57

our Sentiments upon this Head to one another. Let us meet in the great Walk of the *Tuileries* to Morrow at five a Clock in the Evening. Sometimes Philosophy takes Pleasure in the Beau-monde; it discovers the Truth even in the very midst of those who are amused with Lies.

Arist. I shall repair to this new *Lyceum*; every Thing invites me thither, the Company, the Beauty of the Place; and the Charms of so fine a Walk cannot fail to afford you a true Idea of Motion.



CONVERSATION VI.

Upon the Nature of Motion.

Eud. **A**H! I am overjoyed to find you at the Place of Appointment. The Parterre, the Flowers, the Statues, wherein Art rivals Nature, those Marbles almost animated, nor any Thing else could detain me longer, as soon as I saw you appear. You was walking there in a philosophical Manner, and with an Air somewhat pensive. Did your Walk give you any agreeable Idea of Motion?

Arist.

Arist. Nothing seems more clear at first than the Idea of Motion, and yet nothing is more obscure when one comes to search thoroughly into it. When I see the Motion of those People, who upon the Terrass calmly enjoy the Pleasures of walking without Philosophy, I imagine I have caught the Idea of Motion; I fancy I see it in the successive Correspondence of my Body to those several Trees, or in the different Degrees of Distance it has with *Æneas* and *Scipio*^m; but whenever I endeavour to examine this Idea, it either escapes me, or becomes obscured. It is lost in real Difficulties, or in those Phantoms of Difficulties which the Mind often frames to itself for no other Reason, than to torment itself to no Purpose.

Eud. Some distinguished Genius's have talked all their Life Time of Motion, without knowing it, or having any true Idea of it.

Arist. Pray, *Eudoxus*, explain to me the Idea you have conceived of it, and by the Light of yours, mine may be cleared up. Do you believe with *M. Descartes*, that Motion is precisely the passing of one Body from the Vicinity of those with which it is immediately furrounded, into the Neighbourhood of some others?

Eud. No; I cannot persuade my self that the Axle-tree of a Post-Chaise, which is con-

^m Two Statues placed at the End of the great Alley.

stantly fixed in the Nave that immediately touches it, can go so swiftly, without Motion, from *Paris* to *Versailles*. A Man who should go round the Earth in the same Cloaths, would do it without moving from home. *M. Descartes* was probably in a laughing Humour, when he said that the Earth carried rapidly about the Sun in a Vortex of ætherial Matter would not move round||.

Arist. Do you think you can find Motion in the successive Correspondence of one Body to divers others?

Eud. I believe not; for from the Beginning of our Walk, I see in these two double Rows of Chesnut-trees a successive Correspondence to divers Bodies: Have they therefore the more Motion? Not at all, unless that while we walk on gravely, they advance with a majestick and imperceptible Pace; unless they are upon the Walk themselves; and unless Fameⁿ be coming to meet us, proportionally as we advance towards Fame.

Arist. I don't believe that Fame is in any Haste to find me out; one has but little Employment for her, when one is only seeking after the Truth. But pray, when we approach towards Fame, there are new Relations of Di-

|| I am apt to believe the Reason why *Des Cartes* gave such an ambiguous Definition of Motion was, that remembering *Galileo's* being put into the Inquisition for asserting the Revolution of the Earth, he was willing to avoid the same cruel Fate.

ⁿ A Statue.

60 CONVERSATION VI.

stance between us; do these new Relations make any Species of Motion?

Eud. When we advance towards the Statue of Fame, the *Louvre* and *Paris* have new Relations of Distance with us, and yet are not the more moved in the least; it is not very necessary that the Impression of our philosophical Walk should set all the Statues of the *Tuileries* a moving, and spread itself all over *Paris*.

Arist. But in Proportion as we advance, the *Louvre* and *Paris* are farther distant from us; and in the Separation and Removal of Bodies Motion is Reciprocal, according to the Judgment of *M. Descartes*.

Eud. I should have been as well pleased if *Descartes* had said that the Swallow, which reposes itself upon the Cock of *St. Genevieve*, whose Church contains the Ashes of that great Man, could not fly away but that the Cock must fly with it.

Arist. Tell me then, I pray, what the Motion of a Body is *?

Eud.

“ * Motion is a Translation from one Place to another Place, or
“ a continual Change of Place. Every Body has an Idea of it;
“ and Philosophers have in vain laboured to find a Definition of
“ the simple Idea, and proved with a great deal of Pains, that
“ one may come to be ignorant of a Thing which otherwise
“ every Body knows.

“ Place is the Space taken up by a Body: of which may be said,
“ what has just been said concerning Motion. It is Twofold;
“ True or Absolute, and Relative.

“ Defini-

Upon the Nature of Motion. 61

Eud. It is an active Change of Situation in Relation to some Body considered as if it had only Existence. By this active Change I understand the Assemblage of a Body, of divers Relations of Distance which it acquires successively, and of an actual Force received into it,

“ *Definition 1.* True Place is that Part of immoveable Space, which a Body takes up.

“ *Defin. 2.* Relative Place, which only can be distinguished by our Senses, is the Situation of a Body in Respect of other Bodies.

“ True Place is often changed whilst Relative Place is not, and so reciprocally. Whence arises a *true* and *absolute* Motion, and another Sort called a *Relative* Motion. Whilst a Body moves, Time goes on.

“ Time also is Twofold; *True* or *Absolute*, and *Relative*. *True* Time has no Relation to the Motion of Bodies, nor to the Succession of Ideas in an intelligent Being, but by its Nature it always flows equally.

“ *Defin. 3.* Relative Time is Part of the true Time measured by the Motion of Bodies; and this is the only Time that our Senses perceive.

“ All Motion may become swifter, as likewise a Body may move slower than it did before; and it is very likely that there is no Motion of Bodies wholly equable; whence it follows that *relative* Time differs from *true* Time, which never flows faster nor slower.

“ *Defin. 4.* That Affection of Motion, by which a Body runs thro’ certain Space in a certain Time is called Celerity or Velocity, which is greater or less according to the Bigness of that Space, to which it is always proportional.

“ *Defin. 5.* The greater Force is impressed upon a Body to make it change its Place, the greater is its Motion; and that Force is called the *Quantity* or *Momentum* of Motion.

“ *Defin. 6.* The Direction of Motion, is in a right Line, which we suppose drawn towards the Place where the moving Body tends.

“ *Defin. 7.* A Power is any Force acting upon a Body to move it.

“ *Defin. 8.* The greatness of that Force is called, the *Intensity* of the Power. Vide *Gravesande’s Elements*. c. 6.

and

and which alone can give it those different Relations. Now Motion is a Conjunction of those three Things, I can discern them all three exactly in the Motion of my walking.

1. I there see a Body; since this Motion is the Mode of a Body moved, and the Mode of a Body is nothing but a Body modified.
2. This Motion implies divers successive Relations of Distance: For when I sit down, no one will pretend to say that I advance toward *Æneas* or *Scipio*; because no successive Relations of Distance are perceived between us.
3. This Motion implies an actual Force, received into the Body moved, which is called the moving Force; for the different and successive Relations of Distance alone, with these Trees for Example, or with any Statues, are not Motion, unless these Trees and the Statues of *Apollo*, *Diana* and *Orpheus*, which have every Moment divers Relations of Distance, and which are sometimes nearer to us and sometimes farther from us, walk along with us. There is nothing more that offers in the Motion of my Walk. Therefore Motion is an active Change of Situation, &c.

Whenever Bodies contained in the World change their Situation, they pass, they are carried from one Point to another in this vast Space; for which Reason these Terms, *A passing or Carriage from one Place to another*, may be used, as they are, and we shall use them likewise in order to express the Motion of those Bodies.

Arist.

Upon the Nature of Bodies. 63

Arist. The Lady who rides in her Coach over against us in the *Elysian Fields*, does not then move, since she acquires no new Distances with respect to her Coach.

Eudox. Motion is relative. She does not move with respect to her Coach, but moves as her Coach does with respect to us and the *Tuilleries*.

Arist. Can a Boat move upon the *Seine*, that is equally driven toward *Paris* and toward *Chaillot* by the opposite Forces of the Wind and Water?

Eudox. No.

Arist. Nevertheless it would have new Relations of Distance with the Air and Water every Moment.

Eudox. True: But then these would be only external Relations, and not produced precisely by Virtue of any Force received into the Substance of the Boat itself.

Arist. Suppose a Man should walk upon the Boat from East to West, with a Velocity equal to that which carries the Boat from West to East.

Eudox. This Man moves really with respect to the Boat, because by an actual Force precisely which he receives or finds within himself, he acquires different successive Distance with respect to the different Parts of the Boat.

Arist. These successive Relations are they necessary to Motion? Suppose that the Hand
of

64 CONVERSATION VI.

of God should make the Universe turn round upon its Center, and that all the Parts of the Universe keep the same Relations of Distance among themselves: The Universe would then be in Motion without acquiring any new Relations of Distance, seeing there is no Body at all beyond the Bounds of the Universe.

Eudox. 1. At present we have to do with the Motion of particular Bodies only, and not with the Motion of the whole World; and this Hypothesis is good for nothing but to throw into the Mind vain Appearances of Difficulties. 2. According to this Supposition I imagine the Universe would move round, and not move; since it would have no new Relations of Distance.

Arist. One Hypothesis more, *Eudoxus*, and do not lose all Patience. There is need of Courage and Constancy, when one undertakes to instruct others. One Word only, and I yield. There are two Balls at once created out of this World, and situated so that in the first Instant you may put betwixt them a third Ball of a Foot diameter, which you cannot do in the Second: Do you observe any Motion there?

Eudox. Why should I not? I see new Relations of Distance produced by Virtue of a moving Power, received at least into one of the two Balls.

Arist. Which of the two is moved?

Eudox. That only which receives the moving

Upon the Nature of Motion. 65

ving Power; but both, if the moving Power be divided betwixt them.

Arist. I think at last I conceive the Nature of Motion in general: I go into your Sentiment, *Eudoxus*; therein I find wherewith to resolve my Doubts, and to extricate myself from the trifling Cavils which an excessive Subtlety might raise.

Eudox. Very good! Let us now then define the several Kinds of Motion.

Arist. As for the several Kinds of Motion, I am able to define them. I apprehend what Motion is straight or crooked, perpendicular, oblique, horizontal, circular, elliptic, parabolical, proper, common, simple, compound, direct, &c.

1. Motion is straight, crooked, perpendicular, oblique, &c. according to the Line which it describes. Should it describe a straight Line, it is straight. Should it describe a crooked Line, it is crooked, &c. The Motion of this *Jet d'Eau*, which inclines neither to one Side nor the other, and whose Waters fall back upon themselves, is straight and perpendicular. The Bullet would go from this Place with an oblique Motion in Search of the Turtle perched upon the Top of that Tree at twenty Paces distance from us. It would go in an horizontal Motion to strike that Partridge which files off at about the Height of the Sportman's Eye. We walk from one end of this Alley to another in a Motion horizontal, or parallel to the

66 CONVERSATION VI.

Horizon. Turn round a Circle, or round the Star °, and the Motion will be circular. Make a Tour exactly round a Ship, 'tis an elliptick Motion. The Cast of a Bomb is parabolical. Turn round a Point always moving proportionally from it, and this will be a spiral Motion. 'Tis by this Motion the Snake encompasses its Head with the Folds of its Body.

2. Proper Motion is the particular Motion of a Body; common Motion carries forward several Bodies at once. Every one of those Horses in that Coach has his proper Motion; but the Motion of the Coach and of the Persons who pass in it along the *Seine*, is a common Motion. These are two Motions which are no Way contrary: For while a Coach goes from *Paris* toward the *Elysian-Fields*, a Fly walks at Liberty upon the Roof of it from the *Elysian Fields* toward *Paris*. Thus upon a Vessel under full Sail, one may walk with the same Ease from Prow to Stern, as from Stern to Prow.

3. Direct Motion is that which proceeds immediately from the Cause of Motion; reflected Motion, or Reflexion, is a Motion whereby a Body recoils upon encountering another. The Motion of Refraction, or Refraction, is a Motion by which a Body leaves the direct Line in passing from one Medium into another, for Example from the Air into Wa-

◦ A Walk near the *Elysian Fields*.

ter ; I throw a Stone obliquely upon the Surface of the *Sein* ; this is a direct Motion: The little Stone recoils toward the other Bank ; this is a Motion of Reflexion. Shoot off a Gun into the Water the Ball penetrates, but quitting the strait Line ; this is a Motion of Refraction.

4. Should the Motion proceed but from one Cause, and be directed but to one Point, it will be a simple Motion. Should it proceed from several Impressions, each in particular capable of giving it a Direction, then it would be compounded. The Motion of an Arrow which should go in a perpendicular Line to pierce that Bird which hovers in the Air, would be simple ; but the Motion of your Billiard-Ball, when it goes to hazard mine, is compounded of a strait Motion which you give it, and of a Motion circular and upon its own Center, which is given it by the Inequalities of the Plane. Every Wheel of this Coach, the Splendour whereof is a Trophie of Vanity, unites two Motions in one compound Motion, the one circular which the Resistance of the uneven Pavement gives it, and the other horizontal which proceeds from the Horses, and makes it advance with so much Velocity and Noise.

5. They call that a perpetual Motion whose Production should be the Effect of Art, and which should no longer need the Assistance of Art to be perpetuated ; such would be the Mo-

tion of a Watch whose Spring would unbend and bend again, and mark out the Hours without any one's touching it. I leave you the Care of finding out this Motion. All the Philosophers are ready to pay to you their Tribute of Praises; and the *Dutch*, faithful in keeping their Promises, will be forward to bestow on you a Share of that Wealth which they go to seek for in the *Indies*..

Eudox. I chuse rather to repose my self, than lose Time in searching for it; let us sit down and dispose our selves to discourse of the Properties which are to be met with in the different Kinds of Motion.

Arist. Come then let us seat our selves, upon Condition that during the Time of our Repose you will tell me in one Word what is Time and Rest. I own that when I ask what Time and Rest is, I think I know them; but if any Person should ask me, I have then no longer any Knowledge of them.

Eudox. Time is the successive Duration of Things created and changeable; let me examine into the Idea of Time never so much, this is all it presents to the Mind. The Parts of this successive Duration are Moments, quarters of Hours, half Hours, Hours, Days, Months, Years, &c.

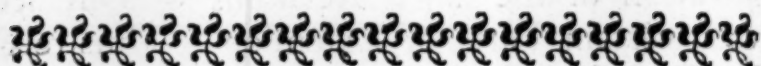
As for Rest, it is the continual Preservation of the same Relations of Distance with the same Parts of Extension. Hence two Sorts of Rest, the one absolute, and the other relative.

Relative

Upon the Nature of Motion. 69

Relative Rest is precisely the continual Preservation of the same Relations of Distance with certain Parts of Extension. Thus relative Rest does not in the least exclude Motion; a Man who sleeps soundly in a Vessel is in relative Rest with respect to the Vessel, because he preserves the same Relations of Distance with the Parts of the Vessel; but he is in real Motion in regard of a thousand other Bodies, with which he acquires new Relations of Distance by the sole Virtue of a moving Power which he receives in himself. What is absolute Rest? It is the continual Preservation of the same Relations of Distance without a Power whose Efficacy alone can give new Relations. Is there any absolute Rest in the Universe? There is nothing that demonstrates it; for the imperceptible Parts of Bodies, which we look upon as Bodies in rest, may be in real Motion.

But, *Aristus*, my dear *Aristus*, I see an Impertinent who comes directly up to us to disturb and interrupt our Conversation; I am under a Necessity of hearing him, and speaking a Word to him in private. Farewell; to Morrow at the same Hour, and in this same Place, we will examine the Properties of Motion.



CONVERSATION VII.

Upon the Properties of Motion.

Arist. I Must acknowledge, *Eudoxus*, it is much easier to walk than to comprehend well what walking is. One often walks without knowing what one does. I admire the Tranquillity of those People whom I see tasting the Pleasures of walking without any Solitude about the Nature and Properties of their Motions; tho' I no wise envy them. The Pleasure of conceiving what walking is, has something in it more agreeable than the Pleasure of walking itself. Thanks to your Instructions I know pretty well the Nature of Motion in general, and of the several Kinds of it: But what Method will you take to unfold its essential Properties? Do I beseech you, as precisely as you can. I will listen to you, without interrupting you. I find more Satisfaction in hearing you than in speaking my self. When I hear you, I imagine I am listening to Reason itself.

Eudox. Let us lay aside all Complements; they are very seldom accompanied with Truth. All Bodies, *Aristus*, that are moved, advance

Upon the Properties of Motion. 71

advance towards one Place, rather than another. They do not advance without running through some Space in a certain Time. They do not run through this Space without having some Force diffused through all their Parts, in order to overcome all Obstacles. Hence there are three essential Properties of Motion, the Determination, Celerity and Quantity.

1. What is the Determination of Motion?

It is the Direction of Motion towards one Side rather than another; for Example, toward the *Invalids*, rather than the *Place des Victoires*; toward *Paris*, rather than *St. Cloud*; toward the East, rather than the West. There are two Sorts of Determinations, the one Simple, the other Compound. The first proceeds but from one Cause, from one single Impression, which directs the Body towards one particular Place: The other from several, capable of directing it towards different Places. The Direction which my Soul gives my Body towards *Apollo*, ^p rather than towards *Diana* ^q, is a simple Determination or Direction. When you pass over the *Seine* obliquely from the *Quatre Nations* to the *Louvre*, the Boat receives from the Rowers and the Water two Impressions, for the following two Lines, which would make a Square: The Impression of the Rowers carries it toward the Point of the other Bank directly opposite; the Impression of the

^p 9 Statues.

72 CONVERSATION VII.

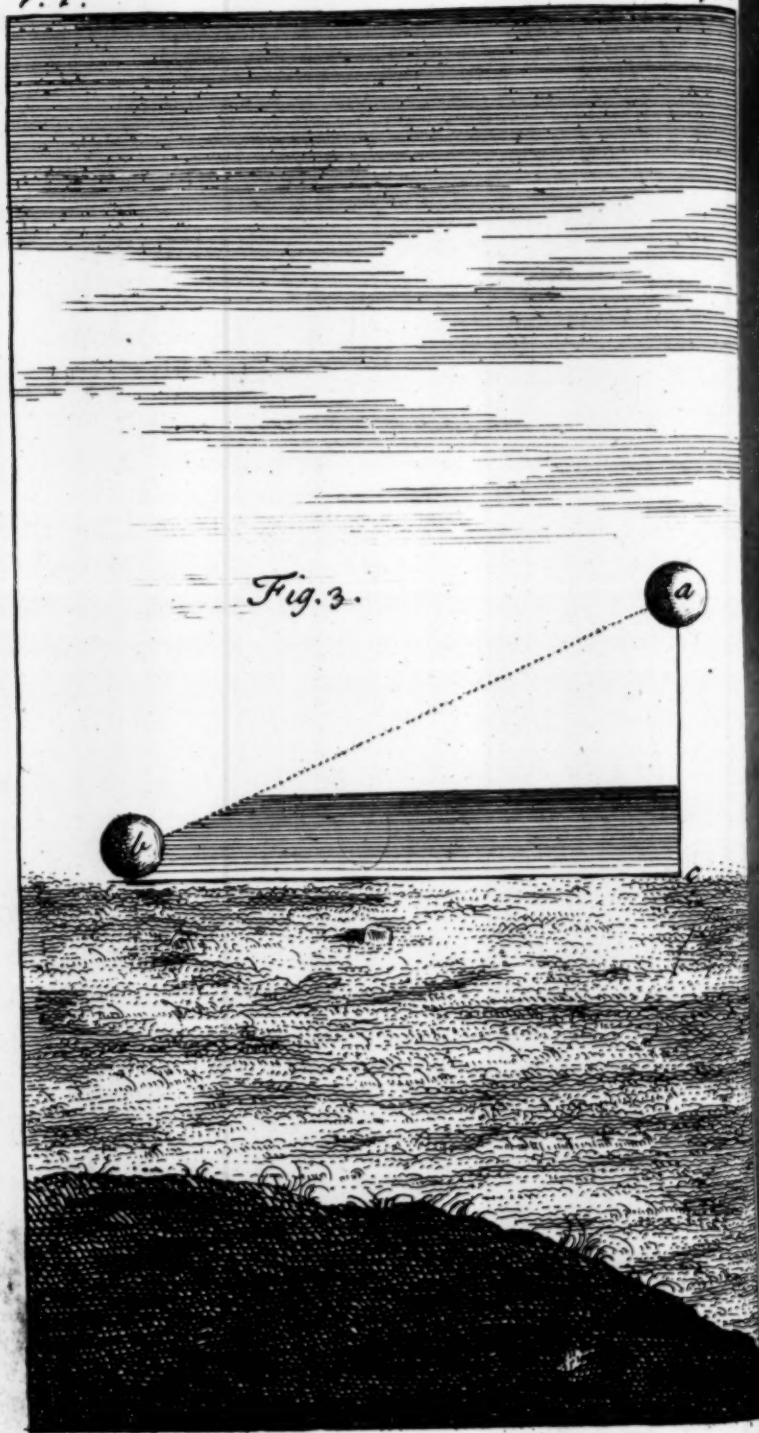
Water toward the *Pont-Royal*, according to the Current of the Water itself. The Boat yields, in some Measure, to the two Impreffions, takes the middle Courfe, and gains the Bank in an oblique Line; and this Determination or Direction is compounded.

2. What is the Velocity of Motion? It is the Relation of the Motion both to the Length of Time, and of the Space run through in a certain Time; the Velocity answers to the Length of Time and Space. Why do they term the Celerity of a Thunderbolt immense? Because it comes instantly from the Cloud to strike the Head of a Criminal.

There are two Sorts of Velocity; the one absolute, the other relative. Absolute Velocity is the Celerity of a Body considered without Relation to any other. Relative Velocity is the Celerity of one Body considered with Relation to some other. The Velocity of my Pace, considered precisely as the Velocity of my Pace, is absolute Velocity; but the Velocity of my Pace, considered as exceeding yours, and unpolitely leaving you behind, is a relative Velocity. Would you measure Velocity, whether absolute or relative? Have no Regard either to the Mass or the Bulk. The Mass, or Quantity, is the Collection of solid Parts, which compose the Body; the Bulk is the apparent Extent of those Parts. The Celerity is neither measured by the Collection of solid Parts, nor by the Extent which strikes the Senses.

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Upon the Properties of Motion. 73

73.
This Person here out of Breath, who is scarcely able to bear himself along, so much Mass and Bulk has he, shews more of it to Appearance than any Body; does he move then with the greater Celerity?

By what then is the Velocity measured? By the Length of Time, and of the Space run through. Divide, as you please, the Length of this Space into several Parts; into Points, Inches, or Feet which are called Degrees: The Degrees run through in a certain Time, express the Degrees of the absolute Velocity of a Body.

Should two Bodies remove from one another, or advance towards one another; add the Degrees of the absolute Celerity of the one, to the Degrees of that of the other, and you will have in the Addition their relative Velocity. Should one Body follow another with some Excess of Velocity, this same Excess is the relative Velocity of those Bodies. In a Word, 'tis by this Excess only that they approach nigher to one another. Should one Body fall in a perpendicular Line upon another, its relative Velocity is the same with its absolute. Should it fall in an oblique Line upon an immoveable Plane, *Fig. 3.* its relative Velocity is measured not by the Length or Degrees of the oblique Line run through (*ab*), but by the Length or Degrees of the perpendicular Line (*ac*), drawn from the Point from which it falls, to the Plane itself; because the

Excess

74 CONVERSATION VII.

Excess of the oblique Line above the Perpendicular is of no Service in approaching towards the Plane.

3. What is the Quantity of Motion? It is that Force with which it strikes Bodies which happen to encounter it. There are two Sorts of Quantity; the one absolute, the other relative. The First is a Quantity considered precisely in itself; the Second is one Quantity compared with another.

The Quantity of Motion, whether absolute or relative, is equally measured, both by the Mass or Greatness, and the Celerity. For, in short, the Quantity of Motion is the Force of a Body moved: And the Force of a Body moved, is measured equally by those two Things; since the same Excess of Mass or Celerity, produces the same Excess in the Shock. Let a Body of two Pounds move with the Velocity of four Degrees, or let a Body of four Pounds move with the Velocity of two Degrees, the Pressure is the same in its encountering another Body. Therefore the Quantity of Motion is equally measured both by the Mass and the Celerity.

In a Word, the Quantity of Motion is equally measured, both by the Mass and the Velocity, if the Force which carries a Body of two Pounds in one Moment to a Foot Distance, and a Force which carries a Body of one Pound in the same Moment to two Foot Distance, are equal Forces: But these are equal

Upon the Properties of Motion. 75

qual Forces; for that Force which carries a Body of two Pounds in one Moment to one Foot Distance, is a Force which in one Moment carries one Pound to one Foot Distance, and another Pound to another: The Force which carries one Pound to two Foot Distance in an Instant, is a Force which in an Instant carries one Pound to one Foot Distance, and the same Pound to another Foot: But the Force which in an Instant carries one Pound one Foot, and another Pound to one Foot; and the Force which in an Instant carries one Pound to one Foot, and the same Pound to another Foot, are equal Forces: Therefore the Force which in an Instant carries a Body of two Pounds to one Foot distance, and the Force which in an Instant carries a Body of one Pound to two Foot Distance, are equal Forces; therefore the Quantity of Motion is equally measured both by the Mass and the Velocity. In like Manner, Experience teaches us, that in order to move a double Body with the same Celerity, or the same Body with a double Celerity, we must equally double the Forces.

If the Question be to determine the relative Quantity of Motion, in order to that I begin with dividing the Velocity of two Bodies into equal Degrees; then I likewise divide at Pleasure the Mass into equal Degrees or Parts, *e. g.* into Pounds. Then I multiply the Degrees of the Mass of each Body by the Degrees of Velocity, or the Degrees of Velocity by the Degrees of the Mass. The Product of each Multiplication

76 CONVERSATION VII.

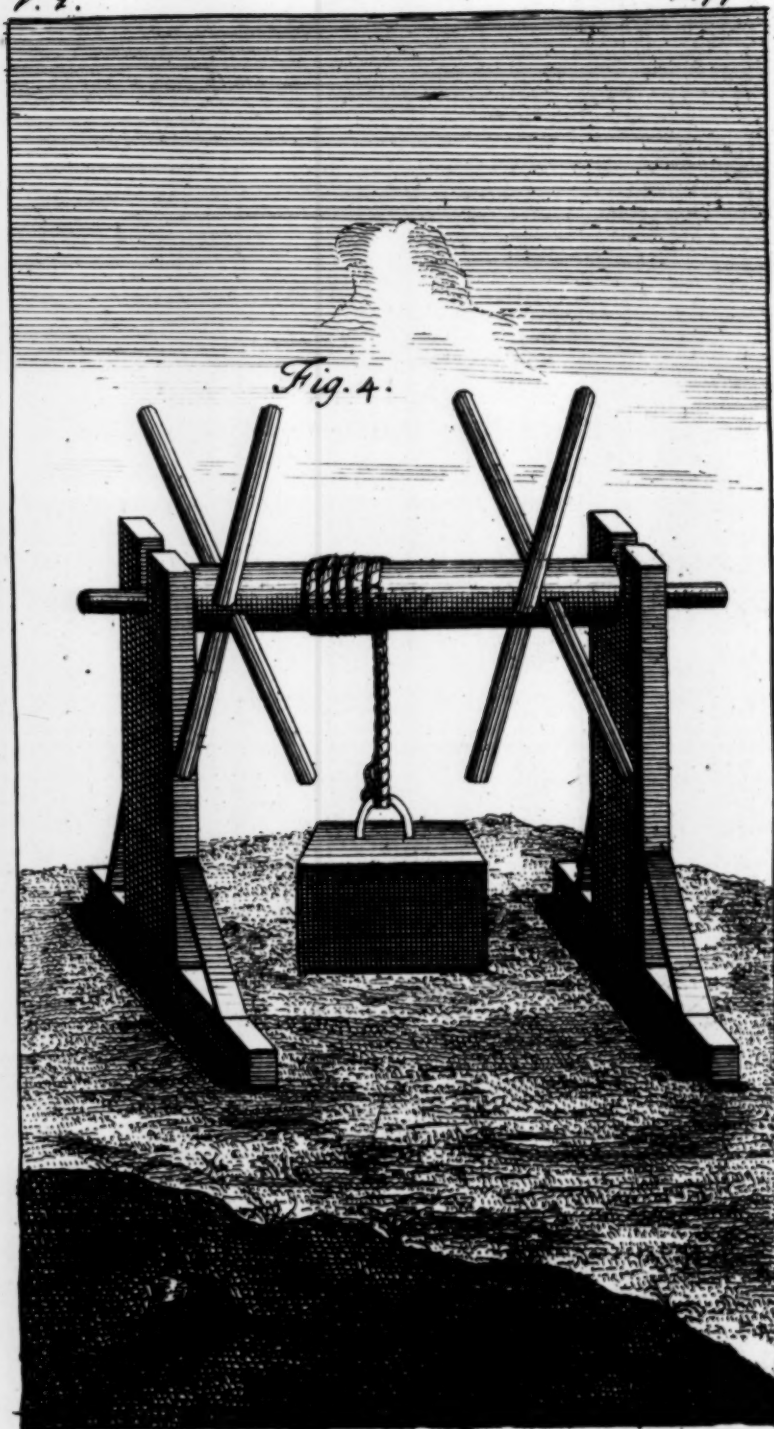
tiplication gives us the Quantity of the Motion of each Body. Is the Velocity of a Body 4 Degrees, and the Mass 3? I must multiply 4 by 3, or 3 by 4. The Product is 12. And this is 12 Degrees of Motion. Is the Velocity of the other Body 2 Degrees, and the Mass 4? I multiply 2 by 4, it produces 8. Thus I determine the Force of one Body with Respect to another.

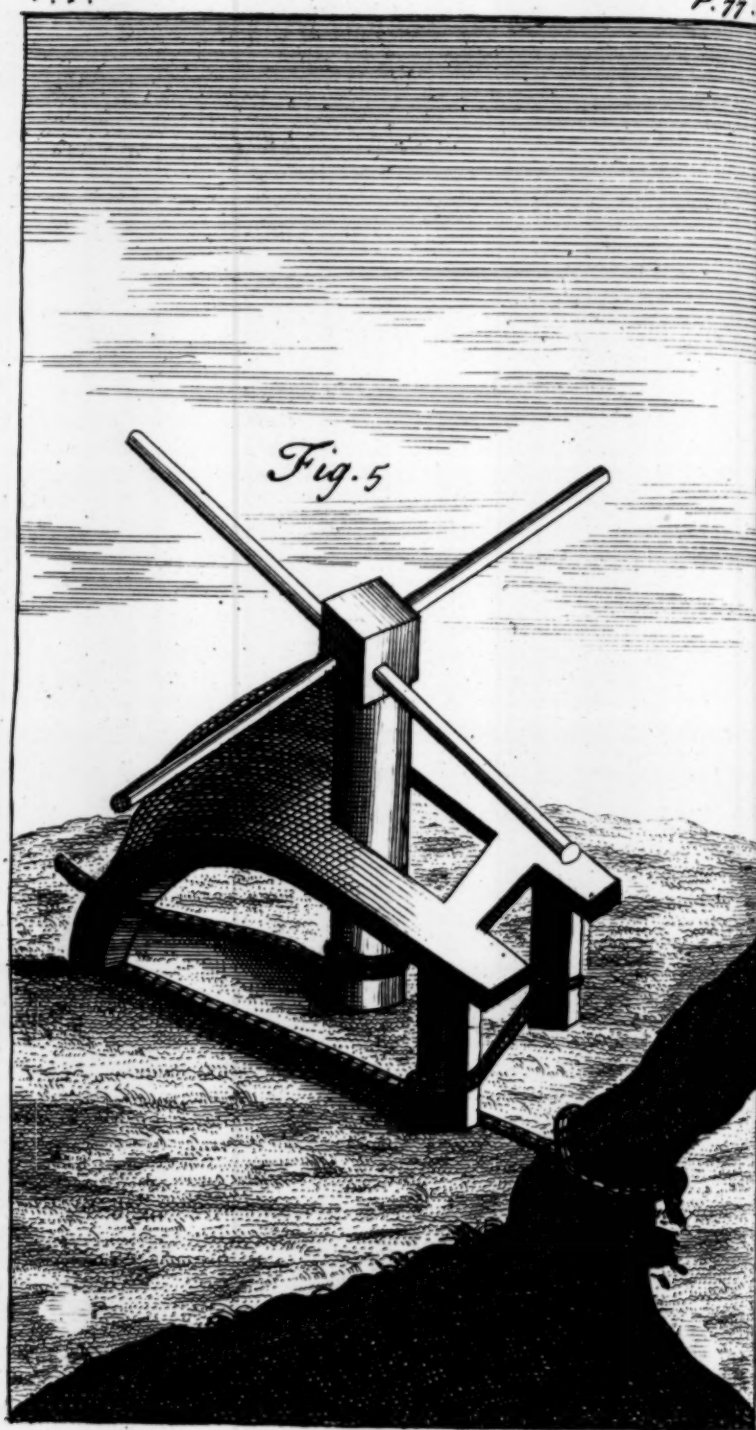
Arist. But I don't yet clearly see how the Product of the Velocity by the Mass, or of the Mass by the Velocity, expresses the Quantity of Motion.

Eud. The Force or Quantity of Motion gives every Part of the Mass its Velocity, equal to the Velocity of the Mass in general; since in the same Time every Part runs the same Length of Way as the whole Mass. Therefore the Force answers to the Number of Parts, and to the Velocities of the Parts, or to the Degrees of the Velocity of the Mass, taken so many Times as the Mass has Parts. Therefore the Product of the Velocity, multiplied by the Degrees of the Mass, or the Mass multiplied by the Degrees of Velocity, ought to express exactly the Quantity of Motion, or the Degrees of Force, which are found in the Body.

Arist. I perfectly apprehend your Meaning. The Determination of Motion is its Direction towards one Part rather than towards another. The Velocity of Motion is its Relation to the
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77.
Upon the Properties of Motion. 77

greater or smaller Length, both of the Time and of the Space run through in that Time. The Quantity of Motion is its Force express'd by the Product, either of the Velocity by the Mass, or of the Mass by the Velocity.

Eud. Hence when two unequal Bodies are in a reciprocal *Ratio*, that is, when the one has more or less Mass, in Proportion as the other has more or less Celerity, they have equal Quantities or Forces of Motion. Are they not in a reciprocal *Ratio*? Their Powers are unequal. Though I walk this Moment as slowly as you do, or have precisely the same Celerity that you have, yet I have more Motion than you, because I have more Height, and you have a Shape more slender and thin. This is the general Principle of Mechanicks, a Science so happy for improving Arts by the Knowledge and Help of Machines, especially since the Foundation of the Royal Academy of Sciences. In this Principle alone you find at once the Knowledge of the surprizing Effects which the Curious take Pleasure to observe in divers Leavers, in the *Roman* Ballance, Oars, Jacks, the Wheels of Water-Mills, the Wings of Wind-Mills, the Handle of Coffee-Mills, the Roll of an Hand-Mill, *Fig. 4*, the Capstan, *Fig. 5*. the Poles of Rope-Dancers, the Wedge, &c.

Arist. What Method do you take, *Eudoxus*, to find at once in this single Principle the
Know-

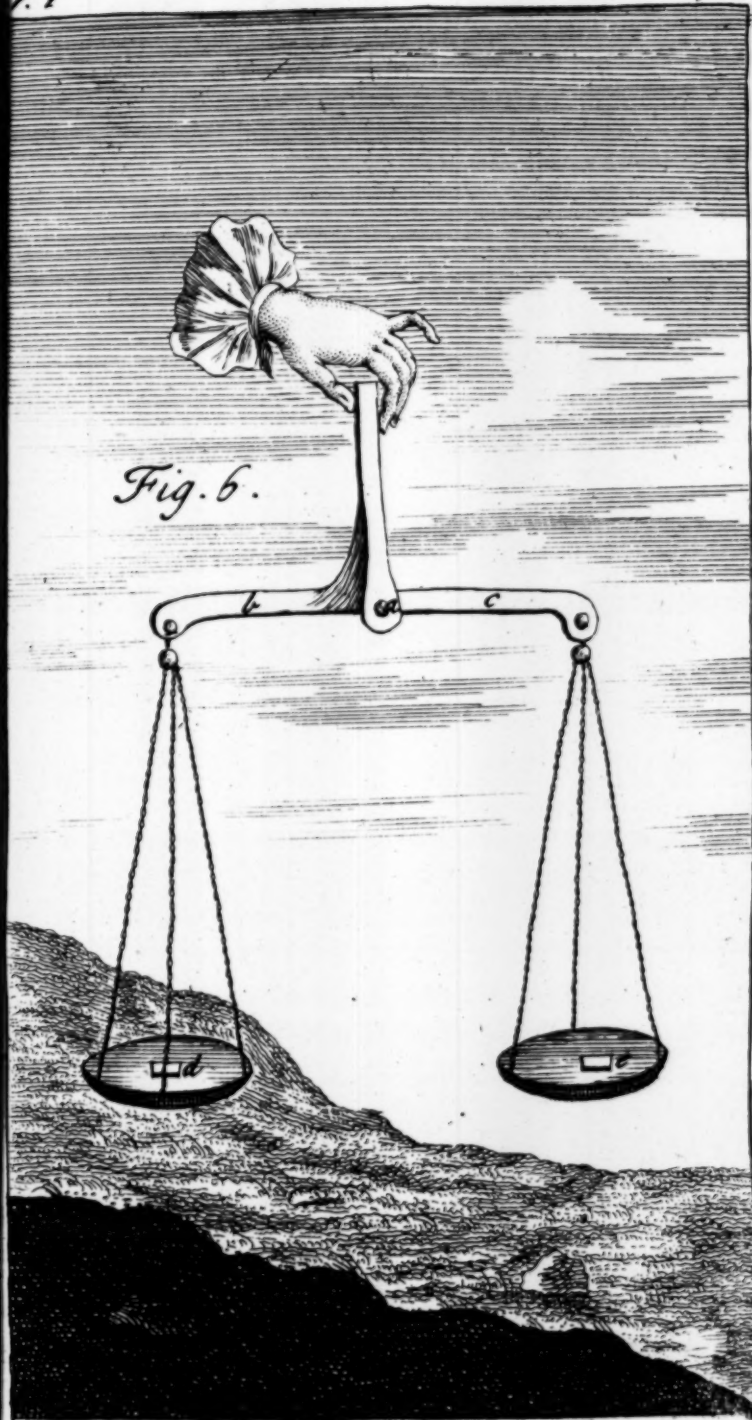
78 CONVERSATION VII.

Knowledge of so many Things, which as yet appear to me unintelligible?

Eud. In a Machine I distinguish the Center, the Distances, and the Weight. I call the Center a fixed Point, or Point of Suspension, the Point by which the Machine is supported, fastened, or suspended. I call the Distance or Beam, the Line or Extent which is found between the fixed Point and the Extremity of the Machine. I call the Weight, the Forces or Bodies applied after such a Manner to divers Points of the Machine, that they counteract one another. The common Ballance, *Fig. 6.* presents to the Mind at first View a Center, or fixed Point, or Point of Suspension (*a*), Distances or *Radii* (*b, c*), and Weights (*d, e*). Finally, I call *Æquilibrium*, Rest or Immobility, produced by Causes which have a contrary Tendency, but are of equal Forces, and equal Motions.

Two unequal Weights being situated in a Machine, after such a Manner, that the least of them is farther distant from the Center or fixed Point, in Proportion as it has less Bigness, they cannot move round the Center, but there must be in the least an Excess of Velocity, equal to the Excess of Mass which is found in the greater. The Excess of Velocity answers to the Excess of Distance or Beam; since the Parts of the Beam move so much the more swiftly, the farther distant they are from the Center, as is evidently seen in the *Radii* of

Fig. 6.



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Upon the Properties of Motion. 79

of a Wheel. For it is evident that in these *Radii*, the Parts make so much the more Way in a determinate Time, as they are nearer to the Circumference, and farther distant from the Axle-Tree.

When two unequal Bodies are in the Situation which I just now mentioned, they are said to be in a reciprocal *Ratio* of Weight and Distance from the fixed Point, or of the Mass and the Velocity: If a Weight of one Pound be two Foot distant from the fixed Point, or at the End of a *Radius* of two Foot, while a Body of two Pounds is one Foot distant from the fixt Point, or at the Extremity of a *Radius* of one Foot; the two Bodies are in a reciprocal *Ratio* of the Weights and the Distances from the fixed Point, or of the Mass and the Velocity.

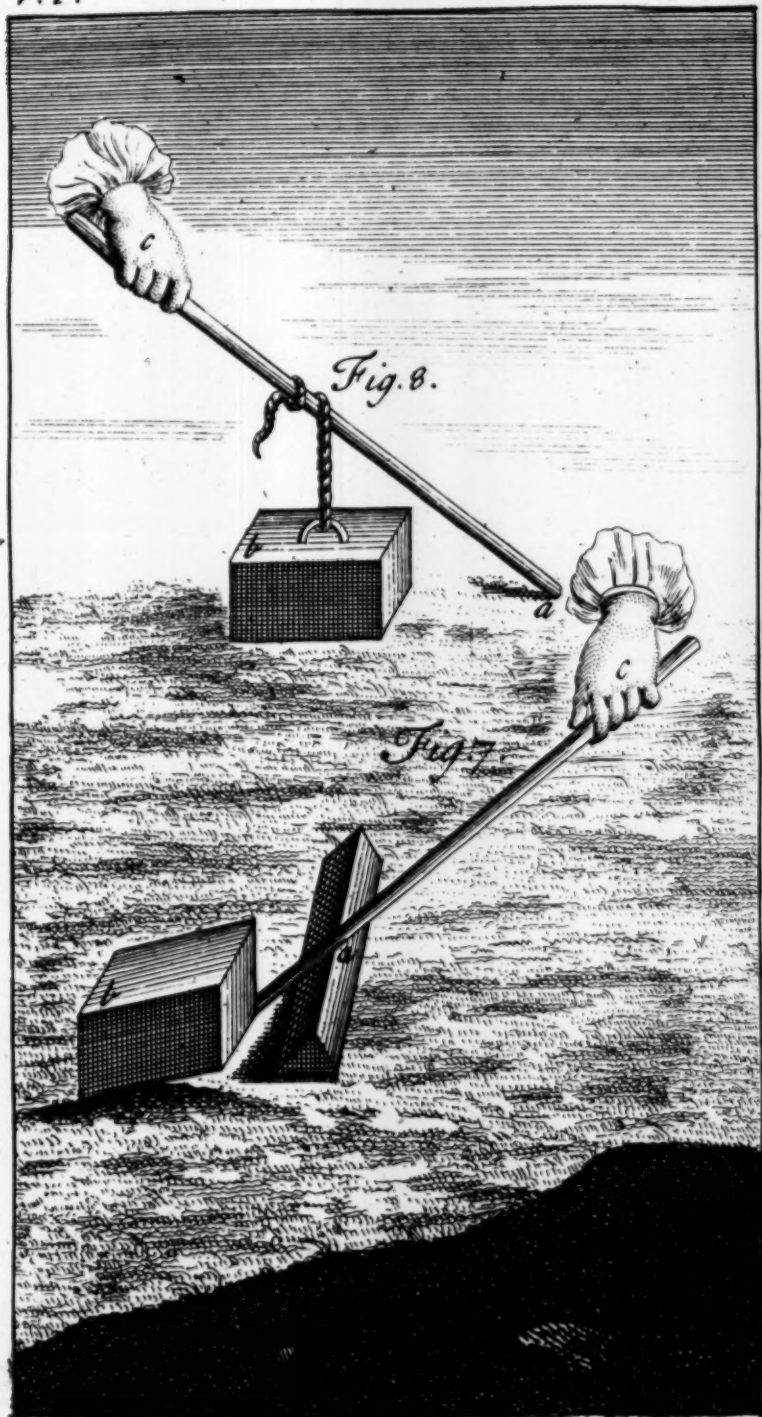
When two unequal Bodies are in a reciprocal *Ratio* of the Weights and the Distances, or of the Mass and Velocity, they are in *Æquilibrio*: For two Bodies are in *Æquilibrio*, when they both equally resist the Effort which they make against one another. But in this Situation two unequal Bodies do both equally resist the Effort which they make against one another. The Resistance is equal to the Motion necessary to move them; and to move them there needs an equal Force, an equal Quantity of Motion, since there must be so much more Swiftness in the least, as there is more Mass in the greatest, and since the Force and Quantity
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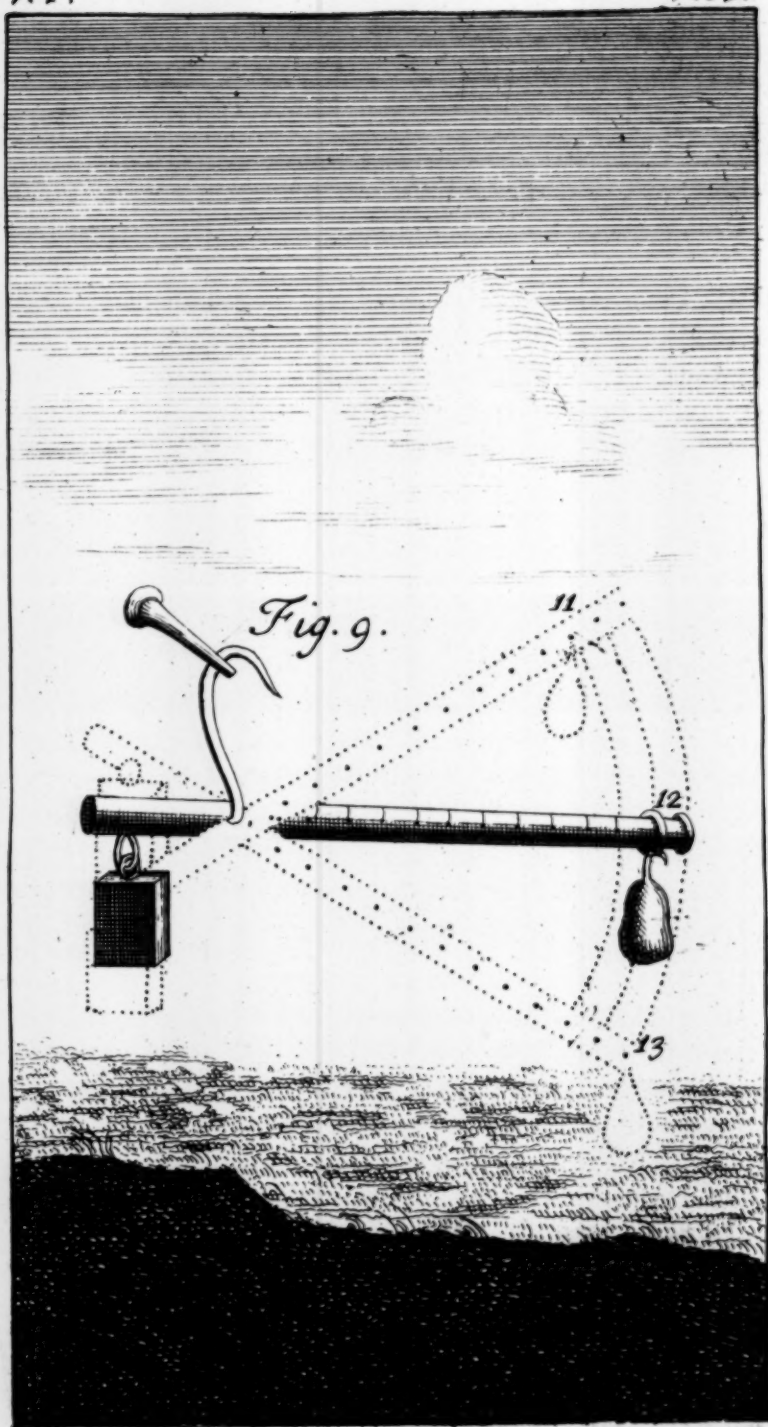
80 CONVERSATION VII.

of Motion are equally measured by the Velocity, and the Mass, as we have demonstrated.

Since two unequal Bodies are *in Æquilibrio*, when they are in a reciprocal *Ratio* of Weight and Distance; by a contrary Reason they are not *in Æquilibrio*, when they are not in a reciprocal *Ratio*. If they are not *in Æquilibrio*, that must give Way which makes the least Resistance, that which requires least Motion to move it, resists less; therefore it ought to give Way, and consequently the other ought to outweigh it.

This being granted, one may immediately conceive the Efficacy of divers Leavers. The Leaver in general is a long Body, of which the Length only comes under Consideration. It has its fixed Point, and two Weights; or one Weight, which is called the Resistance, and a Force equivalent to a Weight, which is called the Power, such as the Hand when applied to one End of the Leaver. If the fixed Point (*a*) *Fig. 7.* be between the Resistance (*b*), and the Power (*c*), it is a Leaver of the first Species. If the Resistance be between the Power and the Point of Suspension, it is a Leaver of the Second, *Fig. 8.* These two Species of Leavers are effectual; why? Because the Power both in the one and the other may be sufficiently removed from the Center or fixed Point, in order to have an Excess of Swiftnes, equal or superior to the Excess of the Greatness of the Resistance,





Upon the Properties of Motion. 81

Resistance, or of the Weight; since the Velocity answers to the Length of the *Radius*.

Hence I can easily explain the *Roman Balance*, *Fig. 9.* which is a Leaver of the first Species: The *Roman Balance* has two unequal *Radii*, united and suspended by a fixed Point. Suppose the smallest be one Inch, and the biggest thirteen. On the End of the smallest I fasten a Weight of twelve Pounds; to the eleventh Inch of the greatest I apply a Weight of one Pound. This Weight yields and ascends. I place it at the twelfth Inch, it remains in *Æquilibrio*. I advance it to the thirteenth Inch, it descends, and the other Weight ascends. Why ought the Weight of one Pound to yield and ascend at the eleventh Inch, remain in *Æquilibrio* at the twelfth, and outweigh and descend at the thirteenth?

1. The Weight of one Pound ought to yield and ascend at the 11th Inch, if it makes a less Resistance to the Effort of the Weight of 12 Pounds, than the Weight of 12 Pounds to the Effort of the Weight of one Pound: But it makes less Resistance; for the Resistance answers to the Force necessary to move it, and to move it there need be only eleven Degrees of Force or Motion, while 12 are necessary for 12 Pounds. In short, while the Weight of 12 Pounds descends one Inch with one Degree of Velocity, the Weight of one Pound ascends eleven Inches precisely with eleven Degrees of Velocity: But a Weight of one Pound, which

82 CONVERSATION VII.

has only eleven Degrees of Velocity, has only eleven Degrees of Motion; a Weight of 12 Pounds, which has one Degree of Velocity, has 12 Degrees of Motion; since the Motion is the Product of the Velocity by the Mass, or of the Mass by the Velocity, the Product of 12 Degrees of Mass by 1 Degree of Velocity is 12, and the Product of 11 Degrees of Velocity by one Degree of Mass, is but 11. Therefore the Weight of one Pound ought to yield, and ascend at the eleventh Inch.

2. Why ought the Weight of one Pound to æquiponderate at the twelfth Inch? The Weight of one Pound ought to æquiponderate, if its Resistance is equal to that of 12 Pounds: But it is equal; for to move both the one and the other, the same Quantity of Motion is necessary. The Weight of 12 Pounds cannot descend one Inch, but the Weight of one Pound must ascend 12 Inches; a Weight of 12 Pounds cannot descend one Inch, nor a Weight of one Pound ascend 12 Inches, without having each of them the same Quantity of Motion, that is to say, 12 Degrees: Motion is equally measured both by the Velocity and the Mass, and one Degree of Mass multiplied by 12 Degrees of Velocity, or one Degree of Velocity multiplied by 12 Degrees of Mass, afford 12 Degrees of Motion: Therefore a Weight of one Pound ought to be in *Æquilibrio* at the twelfth Inch.

3. Why

Upon the Properties of Motion. 83

3. Why ought the Weight of one Pound to descend, being at the thirteenth Inch? The Weight of one Pound ought to descend, if the Weight of 12 Pounds must ascend one Inch: But the Weight of 12 Pounds must ascend one Inch, for it ought to yield and ascend, if it resist less; and it does resist less, since it requires less Force to move it. In short, it moves and ascends one Inch with 12 Degrees of Motion, while the other moves and descends 13 Inches with 13 Degrees of Motion: For the 12 Degrees of Mass of the one, with one Degree of Celerity only, make 12 Degrees of Motion; the 13 Degrees of Velocity of the other, with one Degree of Mass, make 13 Degrees of Motion. Therefore the Weight of one Pound ought to yield, when it is at the 11th Inch; to remain in *Æquilibrio*, when at the 12th; and to outweigh, when at the 13th. Which was the Thing to be demonstrated.

Arist. Since the Efficacy of the smallest Weight or Power, increases in Proportion to its Distance from the fixed Point, the smallest Weight, the least Power which one can imagine, can then outweigh the Resistance of the greatest Weight?

Eud. I require no more, with *Archimedes*, than a fixed Point without the World, and a Leaver of a certain Stiffness and Length, and I will transport the Universe at Pleasure into the imaginary Spaces. A Child would be able to do

84 CONVERSATION VII.

do it by lightly touching the Leaver with the End of his Finger.

Arist. I am not surprized that Scissars cut better near the Rivet than toward the Point. Scissars are two Leavers of the first Species, fastened by a Rivet, which is a fixed Point, or common Center; and the nearer the Resistance is to the Point of Suspension, the more easily it ought to yield. The Efficacy of Pincers proceeds from the same Principle; and I understand why, when with Pincers I lay hold of a Log toward one of its Ends, it rises and obeys with more Difficulty, than when I lay hold on it by the Middle. When I lay hold of it by the End, the other End has so much the more Force to resist, as it is more remote from the Pincers, and from the Point of Suspension. But let us see the Use of your Principle in some Leavers of the second Species.

Eud. The Oar, which makes this Boat pass up toward the *Pont Royal*, is one. The Power is the Hand applied towards the other Extremity of the Oar; the Weight or Resistance is the Boat and its Lading, attach'd to the Oar between the Power and the fixed Point. The Hand or Power has so much more Advantage above the Weight, as it is more remote from the fixed Point, or the Water, than the Weight itself.

Arist. But the Rower's Feet drive the Boat back with as great an Effort, as the Hand makes to carry it forward. Therefore the
Boat

Upon the Properties of Motion. 85

Boat ought to be immoveable, at least in standing Water.

Eud. The Force of the Hand ought to prevail over that of the Feet, if the Force of the Hand be much farther removed from the fixed Point; But it is much farther removed from it. The fixt Point is in the Water, the Hand is at the other End of the Oar, and the Force of the Feet making a part of the Weight or Resistance is, together with the Weight or Resistance toward the Point of Rest, united in the Point of the Oar where it is attach'd to the Boat; therefore the Force of the Oar must prevail over that of the Rower's Feet. And it is this Excess of Force which makes the Boat advance, and, contrary to the Current of the Water, carry Games and Diversions toward the charming Mansions of *Berci*, *Conflans* and *Choiſi*.

Arist. I comprehend why the Hand of the Rower overcomes the contrary Effort of his Feet, and the Current of the Water.

Eud. But do you comprehend how the *Sein* makes this Mill turn round, and how the Water only of one single Rivulet can make it turn, though it have much less Mass and Bulk than the Mill-stone itself?

Arist. Let me think a Moment. Each *Radius* of the Wheel is a Leaver of the first Species. The Water which flows, and is precipitated into the small Cells of the Circumference, is the Power applied to one of the Ex-

86 CONVERSATION VII.

tremities of each *Radius*. Toward the other Extremity is the Point of Support, in the Center of a Cylinder, into which the *Radii* are set. The Weight or Resistance is the little internal Wheel which immediately receives the Motion from the Cylinder that it conveys to the Mill-stone. The Power has so much the more Advantage over the Resistance, as its Beam is the larger; and because the Excess of Velocity in the Power does prevail, the Wheel turns round, the Grain is bruised, and disposed to become proper Food for the Preservation of our Lives.

The Windmill follows the same Principles; its Wings, which are agitated by the Wind are so many Leavers of the same Species, as is also the Handle of a Coffee-Mill. At length I conceive why one has so little Difficulty, and so much Pleasure in the grinding of Coffee.

Eud. Now that which constitutes the Force of the Coffee-Mill, makes up the Force of the Roller, Capstan, Jack, &c. The Wedge passes for a double Leaver of the second Species. The Nail, Knife and Sword are so many Sorts of Wedges, which are driven in so much the more easily, as the Parts separated by those Species of Wedges find in them whereon to support themselves in some Sort, as upon an inclined Plane. The Advantage of an inclined Plane is to be found in the Screw.

Arist.

Upon the general Rules of Motion. 87

Arist. I see perfectly, *Eudoxus*, the Fertility of this Principle, that the Quantity of Motion is equally measured by the Mass, and by the Velocity.

Eud. Well, since we have examined the Determination, the Velocity, the Quantity, and Properties of Motion, we will examine its Rules whenever you please.

Arist. To Morrow at six in the Morning I will repair to your Closet. I know that Philosophers take little Rest, their Search after Truth keeps them awake.



CONVERSATION VIII.

Upon the general Rules of Motion.

Arist. I believe, *Eudoxus*, you will find some Difficulty in instructing me upon this Head. This Morning I saw a Man of Learning, well versed in Antiquity, and who has by the sole Weight of his Authority, filled me with strong Prejudices against your Rules of Motion. He peremptorily affirms without any Ceremony, that those Sorts of Rules are good for nothing, but to overturn the Order of Nature.

Eud. I know not whether your Man of Learning was well awake, for he seems to me to have been in a Dream. Perhaps I am deceived; but in Matter of Physics I don't think one is obliged to yield immediately to the sole Authority of a learned Man. This Victory depends upon the Force of his Reasonings. For my Part, I do not know what they are, but here are mine.

If Bodies do not follow, in their Motions, some constant Rules and Laws established by the Wisdom of the Creator, why do we see every Moment Bodies which move, and continue to move more or less, in Proportion as some foreign Cause comes to determine them sooner or later to rest? Why does every Body that moves circularly, get off in a right Line, whenever it is at Liberty? Why does a Body, which receives divers Impressions at one Time towards different Places, accommodate itself to them all, as much as it can, according as they are stronger or weaker? Why do we see it lose so much the more Motion, the more it causes in other Bodies?

Arist. I freely acknowledge your Reasons affect me more than the Authority of my Man of Learning, who has grown old in his Enquiries after Antiquity, but who seems never to have considered what Nature incessantly presents to his Eyes.

Eud. The Author of Nature, *Aristus*, has made Laws both for Bodies and Spirits; and
in

Upon the general Rules of Motion. 89

in the Observation of those Laws I see a surprising Difference: That is, that Spirits abuse Reason, in order to violate theirs, while Bodies follow theirs constantly, and without degenerating, as if they were reasonable.

Arist. Pray let us unfold those Laws or Rules so faithfully observed by Bodies.

Eud. In order to do so, let us begin with laying down some Principles.

1. Motion and Rest are the two States of Bodies: For constant Modes of Bodies are their States, and Motion and Rest are the constant Modes of Bodies, since both the one and the other consists in a Sort of Continuation; Motion in a successive Continuation, and Rest in a permanent Continuation.

Arist. According to this Principle, *Ovid* seems to have been a Philosopher, and also something of a *Cartesian*, when he found Constancy even in the Inconstancy of Fortune:

Et tantum constans in levitate sua est.

Eud. 2. Body can give itself neither Motion nor Rest; and of itself is wholly indifferent as to the one or the other. In a Word, it has of its own Property no Force, no Efficacy; it is only a Portion of Extension: It has nothing of itself and of its own Stock beside Length, Breadth and Thickness; the Idea of Body offers nothing else to the Mind.

3. As

90 CONVERSATION VIII.

3. As Body is indifferent either to Motion or Rest, by the same Reason it is so either to such or such a Direction, or to such or such a Velocity.

Let us examine at present the general Rules, which all Bodies that are moved seem to follow in the Order of Nature: I see four of them†.

Here

† Sir *Isaac Newton* has laid down three, by which we think every Thing that relates to Motion may be explained.

L A W I.

All Bodies continue in their State of Rest or Motion, uniformly in a right Line, except so much as they are forced to change that State by Forces impressed.

To shew how inviolably this Law is observed, we need only consider that no Instance has been ever produced of any Body that did of itself change from Rest to Motion, nor from Motion to Rest; nor when in Motion, alter its Course, but that wherever such Changes happened, there were always evident Causes. If Bodies changed their Places of themselves, all Things would run into Confusion, nor would there be any certain Means to regulate the Actions of the Universe.

Moreover there is in Matter a passive Principle, which Sir *Isaac Newton* very well expresses by the *Vis Inertiæ*, whereby Bodies resist to the utmost of their Power, any Change or Alteration of their State, whatever it be, either of Rest, Motion, or its Direction; and this Resistance is always equal in the same Body, and in different Bodies is proportional to the Quantity of Matter they contain. There is required as much Force to stop a Body in Motion, as is required to put it in Motion, & *vice versa*; and therefore since the same Body equally resists the contrary equal Changes of its State, this Resistance will operate as powerfully to keep a Body in Motion, as to keep it at Rest, and consequently of itself, it can never change its State of Rest, Motion, or Direction; for to change its Direction, is the same Thing as to move of itself another Way. Matter then of itself is so far indifferent to Motion or Rest, that it is no more inclined

to

Upon the general Rules of Motion. 91

Here is the First: A Body that is moved, ought to continue in Motion, until some external and particular Cause determine it to rest.

The

to the one than to the other, and does no less resist a Change from Rest to Motion, than from Motion to Rest. This *Vis Inertiae* is no where more conspicuous than in the sudden Motion of a Vessel full of Liquor upon a Horizontal Plane; at first while the Vessel is moving along the Plane, the Liquor seems to move with a Direction contrary to that of the Vessel, the Water rising on the Hinder Side of the Vessel. Not that there is really any such Motion impressed upon the Liquor, but that by the *Vis Inertiae*, the Water endeavouring to continue in its State of Rest, the Vessel can't immediately communicate its Motion to it, by Reason of its Bulk and fluid State: But the Liquor perseveres in its State of Rest, whilst the Vessel makes forwards, and so seems to move a contrary Way. But when once the Liquor has the Motion of the Vessel intirely communicated to it, and begins to move with a Velocity equal to that of the Vessel, if the Vessel be suddenly stopped, the Liquor continues its Motion, and dashes over the Sides of the Vessel. This *passive* Principle, or *Vis Inertiae*, is essential to Matter, and can neither be intended or remitted in the same Body, but is always proportional to the Quantity of Matter Bodies contain.

Corol. 1. Hence it is evident that no Body put in Motion will naturally, and of itself, move in a *Curve-Line*. For whatever moves in a *Curve-Line*, must in every Point alter its Direction, which, as was said before, no Body can do.

Corol. 2. Hence the great Bodies of this Universe the *Planets*, their *Satellites*, and the *Comets* do not naturally and of themselves (tho' at first put in Motion) move in their respective Orbits, which are *Curve-Lines* returning into themselves, but are kept in them by some attractive Force, which if once suspended, they would for ever run out in right Lines, and consequently the Motions of these great Bodies in their Orbits, do absolutely depend upon this attractive Force, whencesoever it arises.

Corol. 3. Again, hence it follows, that neither Motion nor Rest (I mean not one of them particularly) is essential to Matter, *i. e.* it will be still Matter, in whichsoever of these States it be, and is indeed indifferent to both, or equally susceptible of either.

LAW

92 CONVERSATION VIII.

The Second : A Body which moves describes, or tends to describe a straight Line.

The Third : A Body that moves by the Force of divers Impressions towards different Places, but

LAW II.

The Changes made in the Motions of Bodies are always proportional to the impress'd moving Force, and are produced in the same Direction with that of the moving Force.

Effects are always proportional to their *adequate* Causes ; and if any Degree of Force produce any Degree of Motion, a double Degree of the same Force will produce a double Degree of Motion, and a triple a triple, and so on ; and this Motion must proceed in the same Direction with that of the moving Force, since from this only the Motion arises : And because by the former Law, Bodies in Motion cannot change their Direction of themselves, so that unless some new Force alter its Course, the Body must proceed in the same Direction with that of the moving Force. And if the Body was before in Motion, the Motion arising from this impress'd Force, if in the same Direction, does so much encrease the former Motion, if it has a contrary Direction, it destroys a Part of the former Motion, equal to that which is impressed ; when it has a Direction oblique to that of the former Motion, it is either added to, or subtracted from the former Motion, according as the Motion arising from a Composition of these two is determined.

Coroll. Hence it is evident, that in the present Constitution of Things, there can be no perpetual Motion. By a perpetual Motion, I mean an uninterrupted Communication of the same Degree of Motion from one Part of Matter to another in a Circle : Not as Bodies put in Motion do for ever continue in the same, but in so far as they are resisted or stopp'd by other Bodies, but a Circulation of the same Quantity of Motion, so that it perpetually returns undiminished upon the *first Mover*. For by this Law the Motion produced is but proportional to the generating Force ; and all Motions on this Globe being performed in a resisting Fluid, *viz.* the Air, a considerable Quantity of the Motion must be spent in the Communication on this *Medium* ; and consequently it is impossible the same Quantity of Motion should return undiminished upon the *first Mover*, which is necessary to-
ward

Upon the general Rules of Motion. 93

but which are not diametrically opposite, complies with them all at once, as much as possible in Proportion to their Forces.

The Fourth : A Body that is moved, and in the End loses its Motion, loses it by Communication ;

ward a perpetual Motion. Moreover, the Nature of material Organs is such, that there is no avoiding a greater or lesser Degree of Friction, tho' the Machine be formed according to the exactest Principles of *Geometry* and *Mechanicks*, there being no perfect Congruity or exact Smoothness in Nature ; the Manner of the Cohesion of Bodies, the small Proportion the solid Matter bears to the Vacuities in them, and the Nature of the constituent Particles of Bodies, not admitting the same. Besides, how very imperfect our most finished mechanick Performances are, a very ordinary Microscope will easily discover. Now these Things must very considerably diminish the communicated Force, so that it is impossible there should be a perpetual Motion, unless the communicated Force were so much greater than the generating Force, as to recompense the Diminution made therein by all these Causes, so that the impressed Motion may return undiminished to the first Mover : But that being contrary to this Law, it is clear, that the Motion must continually decrease, till it at last stop, and consequently there can be no perpetual Motion in the present State of Things.

L A W III.

Repulse or Reaction is always equal to Impulse or Action, or the Action of two Bodies upon one another, is always equal, but with a contrary Direction, i. e. The same Force with which one Body strikes upon another, is returned upon the first by that other ; but these Forces are impressed with contrary Directions.

Whatever presses or draws another, is as much press'd or drawn by that other : If one presses a Stone with his Finger, the Stone presses his Finger again. If a Horse draw forward a Stone by a Rope, the Stone does equally draw back the Horse ; for the Rope being equally distended both Ways, acts upon both equally. If one strike an Anvil with a Hammer, the Anvil strikes the Hammer with equal Force. The Steel draws the Magnet as much as the

94 CONVERSATION VIII.

nication ; that is to say, one Body which strikes against another, loses of its Motion proportionally, as it causes Motion in the other. Let us consider some Particulars for the Proof of the Effects of every Rule.

R U L E I.

A Body which is moved continues in Motion until some external and particular Cause determine it to rest.

I demonstrate it thus : A Body passes from Motion to rest of itself, or the Author of Nature makes it pass without the Encounter of an external and particular Cause ; or the Body continues to move, as the Rule says : But, a
Body

the Magnet does the Steel, as is evident, by making both swim in Water : So in pulling a Barge to Land by a Rope, the Barge pulls the Bank as much as the Bank does the Barge ; and in the Descent of heavy Bodies, the Stone attracts the Earth as much as the Earth does the Stone, *i. e.* the Earth gravitates toward the Stone, as much as the Stone does toward the Earth. And the Motions produced by both these Gravitations are equal in both, only the Stone is altogether inconsiderable, in respect of the Bulk of the Earth ; and consequently the Velocity of the Earth's Motion toward the Stone is inconsiderable, in respect of the Stone's Motion towards the Earth ; and therefore the Motion of the Earth toward the Stone is insensible. And universally in all the Actions of Bodies, if a Body act on another, and change its Motion any Manner of Way, that other will make the same Change in the Motion of this Body, with a contrary Direction ; so that by these Actions there are made equal Changes, not of the Velocities, but of the Motion ; for the Changes made on the Velocities in contrary Directions, are in a reciprocal Proportion to the Quantity of Matter contained in the Bodies. *Vide Cheyne's Philos. Principles, p. 7, &c.*

Upon the general Rules of Motion. 95

Body that moves does not pass from Motion to Rest of itself. Why, and how can it pass of itself from one State to another? It has no Power; it is nothing but a Portion of Extension, which neither has any Force, nor any Interest to repose itself more than to move itself, by the first Principle.

2. The Author of Nature never makes it pass from one State to another, from a State of Motion to that of Rest, without the Action of a particular Cause; even as he never makes it without that pass from Rest to Motion, nor from one Figure to another: But he preserves the Body in the same State, till some particular Cause determine him to preserve it in another. As he is a simple and unchangeable Being, he has made, and observes Simple, constant and uniform Laws, which bear upon them the Impression of his Attributes: Therefore a Body which is moved continues to move, until some external and particular Cause determine it to rest.

Hence, when a Body has received Motion, it may preserve it without the Aid of a particular Cause. Without this Aid, a Stone thrown into the Air ascends, till having insensibly lost its Force by the successive Encounter of divers Parts of Air, it falls again at last by Virtue of its Weight.

Arist. Would a Ball then shot toward the *East*, or toward the *West*, move continually, if it should meet with no Obstacle toward the
same

96 CONVERSATION VIII.

same Place, with the same Direction, and the same Velocity?

Eud. I don't doubt it. A Stone thrown perpendicularly, would continue in an uniform Motion to reach the *Zenith*. The Indifferency of Bodies is alike as to Rest, Motion, Direction, and Velocity. They have no more that Byass to Rest, or to the Center of the Earth, which the antient Philosophers found in them, or imputed to them*.

Arist. But if the moved Body never ceased to move, would not its Motion be infinite?

Eud. It would not properly be infinite, since it would continually double its Velocity.

Arist. I see it; notwithstanding *Aristotle's* Authority, you will not allow that Bodies which are moved, owe the Preservation of their Motion to the Impression of the Air.

Eudox. Because the Air is an Obstacle to Motion, therefore it must be far from continuing it. Put a Pendulum into the Receiver of an Air Pump; and pump out the Air; the Vibrations of the Pendulum will thereby acquire a greater Velocity.

Arist. I am wholly of your Opinion as to the first Rule.

Eud. Let us pass to the second.

* See the Notes on CONVERSAT. XVII. Vol. I.

R U L E II.

Every Body that moves, describes, or tends to describe a straight Line.

I demonstrate it thus: A Body, which of itself preserves the same Direction as much as possible, describes, or tends to describe a straight Line: For to describe a crooked Line is to change the Direction; it is successively to regard divers Points of the World: But every Body that is moved, preserves of itself the same Direction as much as it can; since of itself it cannot change it, and is indifferent either to such or such a Direction, by the third Principle, having no Force, no Interest, no Byass to carry it, rather toward the *East* than toward the *West*, toward the *South* than toward the *North*. Therefore every Body that is moved describes, or tends to describe a straight Line. Accordingly every Body that is forced to describe a Curve Line, runs off in a straight Line whenever it is at Liberty.

Hence, If the moved Body describe precisely, a Square Figure, it must in its Way encounter with four Obstacles. Of itself it would always follow a straight Line; it is altogether a Stranger to Turnings.

2. What is it that causes circular Motion? A Continuance of Obstacles; for a Body that is moved, always endeavours to follow a straight

98 CONVERSATION VIII.

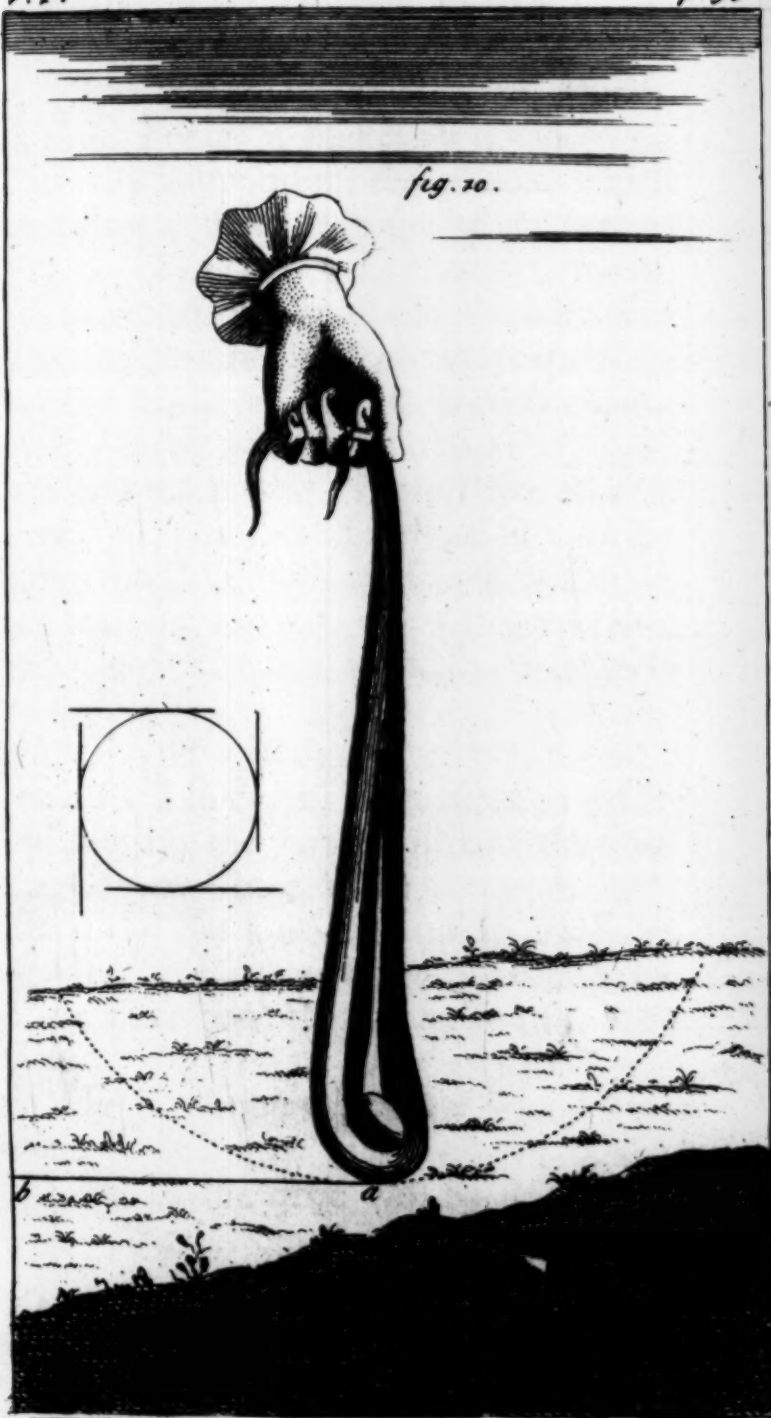
Line; nevertheless it leaves it every Moment. What obliges it to that, if it be not a Continuation of Obstacles?

3. A Body moved circularly endeavours to remove from the Center of its Motion. In a Word, it tends to describe a straight Line; and this Effort removes it from the Center. Make a Stone move round your Hand in a Sling; and your Hand, which is the Center of Motion, feels the Effort which the Stone makes in order to remove. If you make a Vessel full of Water move round in a Sling, the Water is not diffus'd; why? The Effort, which it makes to remove from the Hand, gives it a Direction which removes it from the Brim, and fixes it to the Bottom of the Vessel.

4. A Body that makes an Effort to remove from the Center of its circular Motion, endeavours to go off in a Tangent (*ab*) *Fig. 10.* As the Points of the Circle are so many Beginnings of Tangents, or of straight Lines contained in some Sort upon the Circle, and which only touch it in one Point, the Body that moves round receives in every Point a Direction to follow the Tangent; and you may see it follow the same effectually, whenever it is at Liberty; it follows it whenever it gets out of the Sling.

5. When several Bodies are carried rapidly at once round a common Center, those which are fittest for Motion, and have most Force, make the greatest Effort to remove from the Center.

fig. 10.



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Upon the general Rules of Motion. 99

Center. The Effort of a Body in Motion answers to its Force, it makes all it can.

6. Upon this Supposition, those Bodies which have most Force, drive back the others toward the Center. The stronger cannot remove, without taking the Place of the weaker: For there is no Appearance of Vacuities capable of receiving the stronger; and the weaker cannot yield their Places without withdrawing into those which the stronger have left free toward the Center. If you should agitate in a circular Manner the Corn with the Chaff in a Sieve, the Corn carried toward the Circumference forces the Chaff which is weakest, to unite in the Center.

Finally, Should a Body that moves round a Center be a solid Body, its Parts move so much the more swiftly, the farther distant they are from the Center. In a Wheel, *e. g.* the farther distant the Parts of the Spokes are from the Axle-tree, the more Velocity they have, since in the same time they make so much the more Way.

Arist. The Consequences of the second Rule are evident.

Eud. Those of the third will be no less so.

RULE III.

A Body that is moved by the Efficacy of different Impressions toward different Points, or which receives divers Directions, complies with them all, as much as possible, in Proportion to their Forces.

I demonstrate it thus: 1. It complies with all the Impressions, since it is indifferent to them all, and can of itself refuse none of them. 2. It complies, I say, with all, in Proportion to their Forces; for a greater Force must prevail beyond a less proportionally, as the one is greater, and the other less.

Hence, Suppose you stand upright in a Boat, let it hit against the Bank, it recoils; and while it recoils, if you are not on your Guard, you will fall all along: Why?

Arist. I see the Reason of it. While the Boat recoils, the upper Part of my Body preserves its first Direction toward the Bank: My Feet, being fixed to the Boat, receive a contrary Direction to recoil immediately from the Boat itself. My Body complies with two Directions; the Feet recoil, the Head advances; the middle of my Body being supported by nothing, falls; and thus I come to be laid all along.

Eud. You rise again with some Applause. Then being placed upon a Cylinder endeavour

Eud.

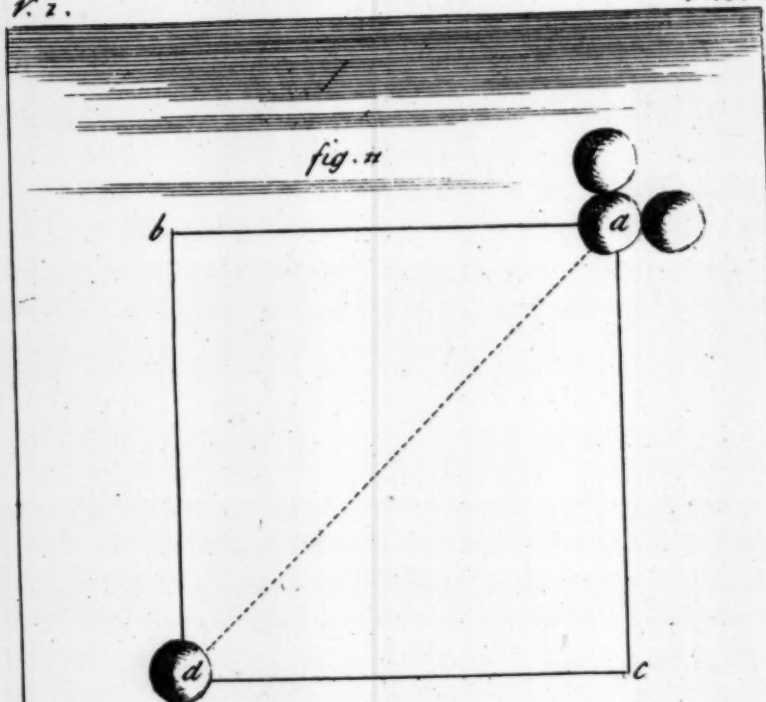
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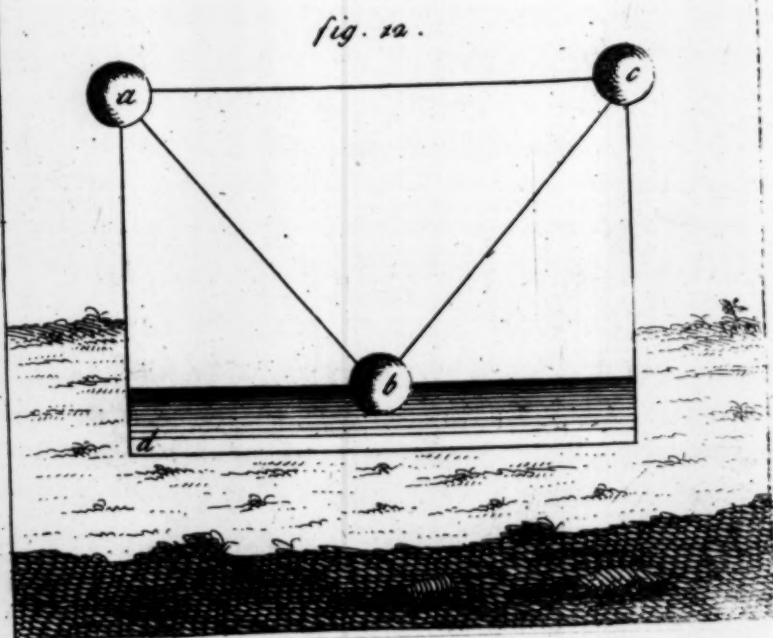
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P. 107.



Upon the general Rules of Motion. 101

to leap forward. What happens upon this Attempt?

Arist. The same Effect; a merry Fall. I give the upper Part of my Body a Direction to go forward, and to my Feet to move backward. My Feet being supported by a moveable Cylinder, follow their Direction, and recoil; my Head follows its Direction, and goes forward. The middle of my Body finds itself without any Support, and I fall with my Nose upon the Ground. This gives me some Confusion, and in spite of all your Philosophic Gravity you do nothing but laugh at it.

Eudox. You are too well acquainted with the Rules of Motion to expose yourself to give this little Scene: But let us seriously examine the principal Consequences of the third Rule. I suppose that a Body receives two Impressions toward different Points that are not diametrically opposite, or two Directions, *Fig. 11.* the one (*ab*) horizontal or parallel to the Horizon and the other (*ac*) perpendicular to the Horizon. What Course will it take?

Arist. A compound oblique and middle Direction will be made up of these two Directions, namely, (*ad*) which approaches the horizontal and perpendicular Directions, more or less, in Proportion to the Force, both of the one and the other, since it ought to yield both to the one and the other in Proportion to their Forces, by the third Rule.

Eud. And as an oblique Direction is formed of two Directions, the one perpendicular, and another parallel, we may say, that the oblique Motion has two Directions, one parallel, and the other perpendicular. In a Word, it brings the Body nearer to divers Points of two Lines, the one parallel, the other perpendicular, which would be the two Sides of a Parallelogram *eg*, of an exact Square, or of an oblong Parallelogram. Nothing more is necessary to understand how the Wind makes a Mill go round.

Arist. This is a thing which appears at first easy to conceive, but nevertheless becomes difficult when one considers it.

Eud. This is the Way I conceive it. The Axis of the Mill is in the Direction of the Wind; the Surface of the Sails making with the Axis, to which they are fastned, an Angle of 55 Degrees, and in a Situation oblique to the Wind. The Wind which blows obliquely upon the Surface of the Sails, has two Directions of oblique Motion, the one parallel, and the other perpendicular to the Surface of the Sails. By the parallel Direction the Wind does not push the Surface of the Sails; for a Direction parallel to a Body does not convey to it the Effort of the Body moved. By the perpendicular Direction the Wind gives an Impression to the Surface of the Sails, in order to drive them backward by an oblique and middle Line, between the Axis and a Line perpendicular

Upon the general Rules of Motion. 103

dicular to it. The Surface of every Sail receives then two Directions from the Wind, one perpendicular to the Axis, and another parallel, which brings it nearer to the Axis. The Surface cannot follow the parallel Direction without breaking: It may freely yield to the perpendicular Direction without Danger, and it does so. But as it is attach'd to the Axis, it is oblig'd to change from a Perpendicular every Moment, which it does. Changing from a straight Line every Moment, it describes a Curve and circular Line, and makes the Axis turn round with it so much the more easily, because every Surface answering to another disposed obliquely, and a contrary Way, the Force which makes one ascend, helps the other to descend; the Force which makes one descend, helps another to ascend: So that the Situation of every Surface conspires to the same circular Motion. Hence the Mechanism of the Mill.

Would you have an Explanation of it more short and simple? The Air being violently driven against the oblique Wings of the Mill, endeavouring to dilate itself every Way by Virtue of its Spring, push the Sails both toward the Mill, and toward the Parts whither they are carried. The Sails cannot approach nearer to the Mill without breaking: They can, without breaking, follow the other Impression; they follow it, and the Mill goes round: But suppose the horizontal and perpendicular Directions

be always equal, what Species of oblique and middle Line will the moved Body describe?

Arist. The Diagonal of a Square; because in this Supposition it ought equally to approach the horizontal and perpendicular Lines, which make two Sides of a Square; and it cannot approach them equally but by the Diagonal, drawn from one Angle to the Angle diametrically opposite. Suppose a Billiard Ball receive in this Corner of your Closet two equal Impressions, one to go along the Wall on the Right, and another to go along the Wall on the Left; this Ball taking a middle Course will run into that Corner directly over against us, that it may equally yield to the two Impressions.

Eud. But if there be any Inequality in the two Impressions, or in the two Directions of a Body, so that the one diminishes every Moment, and the other increases proportionally; what happens?

Arist. The Body moved describes a Curve Line, that is a Parabola: For it describes a Line which changes its Direction every Moment, removing always from that which diminishes; since the prevailing Direction forcing it from the other, carries it every Moment towards a new Point: Now a Line of this Kind is a Curve Line, a Parabola, &c.

Eud. According to this Principle a Canon Bullet describes a Parabolical Line. It receives two Impressions, two Directions, the one horizontal

horizontal or Parallel to the Surface of the Earth, the other perpendicular. That proceeds from the Gun-powder, and this from the Gravity. The first is diminished every Moment by the Resistance of the Air, and the other increases by the repeated Efforts of the Gravity. Increasing every Moment it gives the Bullet new Directions, carries it toward different Points of the Earth, and brings it nearer to the Perpendicular. The Line made up of those Changes of Direction is a crooked Parabolic Line. The same Line is described by the Ball of a Fuzee, for the same Reason. Would you hit a Mark at the End of the Reach of a Cannon or Fuzee? Fix your Eye a little higher: But let me have the Pleasure of perplexing you with some Problems.

The first Problem. Why, I pray, does a Ball, while a Vessel sails full before the Wind, fall from the Scuttle to the Foot of the Mast in a Curve Line, observed by those who look from the Shore?

Arist. The Ball has two unequal Directions, one horizontal, or parallel to the Horizon, which proceeds from the Vessel, and another perpendicular and stronger, which proceeds from the Gravity. The Ball yielding to both in Proportion to their Forces, advances with the Vessel in a Curve Line, which lays it down at the Foot of the Mast.

Eud. 2. Problem. A Ball thrown perpendicularly from the Foot of the Mast, falls again

106 CONVERSATION VIII.

again at the Foot of the Mast, tho' the Vessel be carried forward with Rapidity; why?

Arist. For the same Reason. The Ball obeying its two Impressions proportionally to its two unequal Directions, is carried again by a Curve Line to the Foot of the Mast.

Eud. 3. *Problem.* An Horseman riding full Speed throws an Orange into the Air; the Orange falls again into his Hand; why?

Arist. For the same Reason still. The Orange following the third Rule, yields to its two unequal Impressions agreeably to the Inequality of their Forces, and by a Curve Line meets the Hand again which threw it.

Eud. 4. *Problem.* Now I will give you a more difficult Problem. Upon a Plane, the Plane of a Billiard-Table for Example, with the Edge of my Hand, and a smart Blow, I strike a Billiard Ball about the Middle of its Diameter; the Billiard Ball being struck runs off from under the Hand, and retires in a right Line toward the Hand which struck it: You would imagine it purposed to take Vengeance for the Blow it had received.

Arist. The Ball being struck by an Hand which slides upon its Circumference, and in a Place which does not carry it immediately upon the Plane, receives two Motions at a time, the one straight, and the other circular, and yields to both. By the straight Motion it removes; but this Motion is lost by the Encounter and Resistance of the Air, which it must divide

divide in order to advance. The circular Motion, which does not meet with the same Obstacle, subsists a longer time, and being seconded by the Reaction of the Air, push'd by the straight Motion, it brings back the Ball towards the Hand; while the Ball, wholly indifferent, either to Motion or Rest, thinks nothing of revenging the Blow it has received.

Eud. When one understands what has been said, it is easy to comprehend the Motions of Reflexion and Refraction.

I throw a Billiard Ball obliquely upon a Plane: After the Stroke of the Plane it ascends and passes to the other Side by a reflected Motion. Why?

Arist. The oblique Motion of the Billiard Ball (*ab*) *Fig. 12.* is compounded of two Directions, the one parallel (*ac*) and the other (*ad*) perpendicular to the Plane. The Plane being impenetrable to the Billiard Ball, and directly opposed to the perpendicular Direction downward, changes it into a perpendicular Direction upward: But the parallel Direction remains; as it is parallel to the Plane, it does not encounter the Plane, and the Plane changes it in no Sort. What then must the Billiard Ball do after encountering the Plane? Take a middle Course (*bc*) to yield to those two Directions, according to their Forces. It takes it without fail; and this is the Motion of Reflexion.

Eud.

108 CONVERSATION VIII.

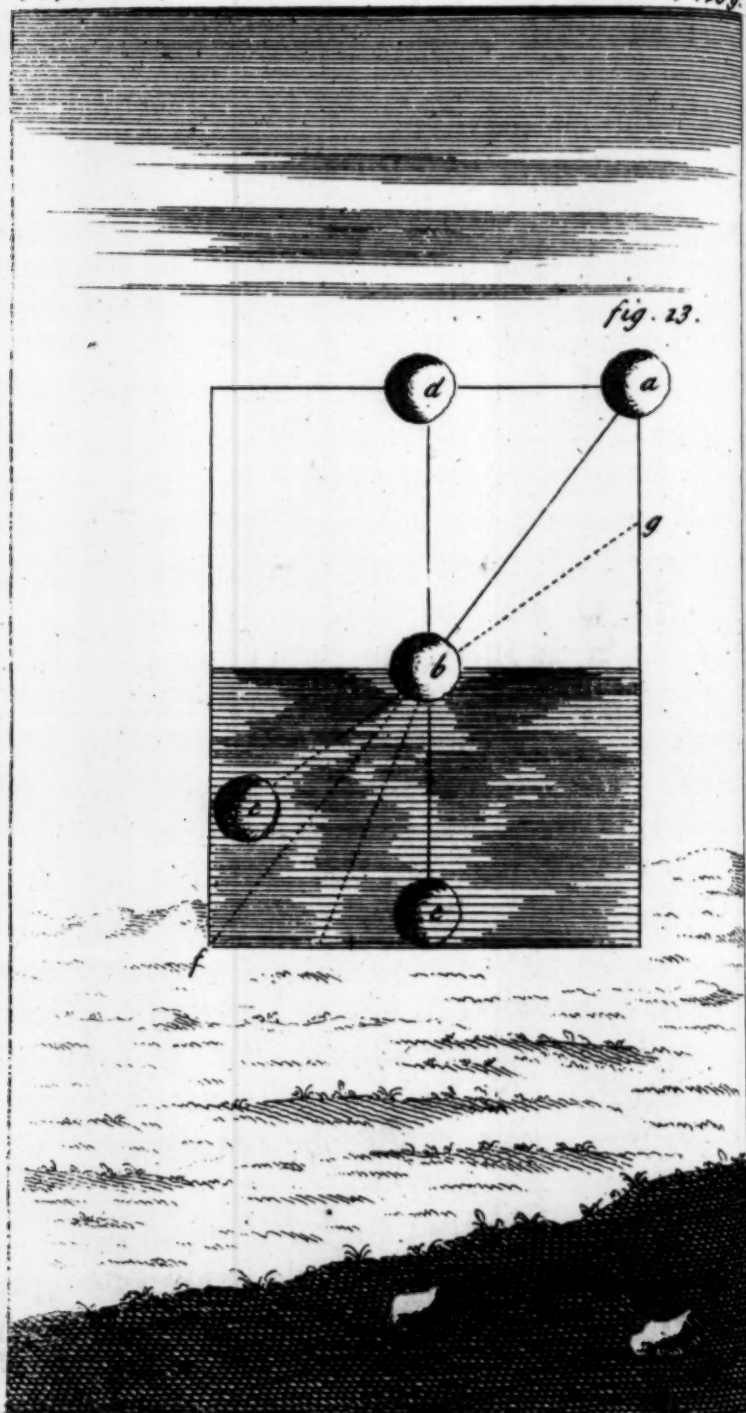
Eud. This Motion of Reflexion makes an Angle with a Plane, which they call an Angle of Reflexion; as the Motion by which the Plane is struck makes with it an Angle, which they call the Angle of Incidence. But ought the Angle of Reflexion to be equal to the Angle of Incidence or not?

Arist. If in the Fall and the Stroke the Body loses nothing of its Force; and that none of the Directions be diminish'd, the Angles ought to be equal; since in the Fall, and after the Stroke, the Body moved ought to describe a Line equally distant from the Parallel and Perpendicular, in order to yield equally to equal Forces and Directions: But if it lose of its Force; if the perpendicular Direction be diminished, and diminished more than the Parallel, as it happens in sensible Bodies, the Angle of Reflexion ought to be less, since the Body moved ought to yield more to the parallel Direction than to the Perpendicular, which is become weaker.

Eud. I think you ought to know at present the Reason of those Undulations on the Water called Ducks and Drakes, as well at least as you knew how to make them, when you was younger.

Arist. The small flat and round Stone, which rapidly and obliquely grazes upon and skips along the Surface of the Water, has its two Directions, the one parallel and much stronger, the other perpendicular downward, and
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much weaker. The Plane of the Water, by its Resistance, immediately changes the perpendicular Direction downwards, into a perpendicular Direction upwards; and the Stone is reflected, according to the Rule, by a mean and oblique Line. Then the Gravity in its Turn changes the perpendicular Direction upward, into a perpendicular Direction downward, while the parallel Direction still continues; and the Stone, obedient to the third Rule, proceeds again by an oblique Line to graze upon the Surface of the Water. This Diverſion continues for the ſame Reason, until the Stone having loſt its Motion, is ſunk by Virtue of its Gravity. It is by the Reason of Ducks and Drakes that a Cannon-Ball, after having grazed upon the Surface of the Sea, is ſometimes reflected ſo as to cauſe Death, even upon the Deck of a Ship.

Eud. But I ſuppoſe that a Body, which is moved (*a, b, c*) *Fig. 13.* paſſes obliquely from one *Medium* into another, from Air, for Example, into Water, or from Water into Air. In the Point of paſſing (*b*) the Line which it deſcribes is broken; it turns aſide a little, ſometimes removing from the perpendicular Line (*d e*), or the Line which paſſes perpendicularly through the two *Mediums*, and ſometimes approaching to the ſaid Line; and theſe are Refractions. How do they happen?

Ariſt. The Body, which paſſes obliquely from one *Medium* into another, has its two
Directi-

110 CONVERSATION VIII.

Directions, one parallel to the Surface of the *Medium*, into which it passes, and the other perpendicular. When it reaches the Surface of a *Medium* that resists more than that from which it comes, as it happens when a Ball passes from Air into Water, it finds a greater Resistance at the perpendicular Direction than at the Parallel; the Excess of Resistance diminishes the perpendicular Direction, while no Excess of Resistance diminishes the Parallel. Therefore after the Diminution of the perpendicular Direction, the Body moved ought to yield less to it, and more to the Parallel. It cannot do so, without removing a little from the perpendicular Line which cuts the two *Mediums*: It removes from it; and this is one Species of Refraction. When it reaches a *Medium* that resists less, it finds more Resistance at the parallel Direction, than at the Perpendicular. After the Diminution of the parallel Direction, the Body moved ought to yield less to it, and more to the other: It cannot do so without approaching to the Line perpendicular to the two *Mediums*; and this is another Sort of Refraction. Hence the Ball (*abc*) which passes obliquely from Air into Water, removes from the Perpendicular (*de*), losing its Tendency to the same Point (*f*). If it pass from Water into Air, it approaches to the Perpendicular (*de*), ceasing to aim at the same Point (*g*). If you design to shoot a Fish in the Water, you must fix your Eye a little lower.

Upon the general Rules of Motion. III

er. The Refraction will make the Ball ascend, and carry it into the Body of the Fish.

Eud. But finally the Motion of Refraction, as well as that of Reflection, curve Motion as well as strait, simple and Compound are lost. How does that happen? Why, thus, as I imagine.

R U L E IV.

Motion that is lost, is lost by Communication.

Motion, I say, is lost by Communication; or Resistance destroys it. But Resistance does not destroy it: For if Resistance did destroy it, since the Stars diffuse their Light every where, and all, or almost all Bodies act one against another, and continually resist each other, in a short Time all Motion would be destroyed, both in the subtile Matter and in the Universe; all Bodies should quickly be frozen, an unhappy Languor would spread itself over all Nature, and the Universe would be reduced to a frightful Chaos.

You will say perhaps that the Spring, or that which restores to compressed Bodies their former Figure, restores also the Motion which they have lost. But ought not the Spring itself to be annihilated? For Body being only a Portion of Matter, is perfectly indifferent to all imaginable Figures. Therefore if after Compression it resume its former Figure, an external Cause must restore it by striking against it.

112 CONVERSATION VIII.

it. This external Cause which strikes it, is a Body. This Body is imperceptible. Therefore it is the Air, or some finer Matter, the subtile Matter. It is not the Air. The Air has its Spring, which depends upon an external Cause. Therefore it is the subtile Matter. But the subtile Matter finding Resistance both in elastic Bodies, and in all that it encounters, would lose its Force. Therefore the Cause of the Spring, and consequently the Spring itself ought, as I think, to be annihilated. Therefore Motion is lost by Communication. Thus we every Day see Bodies continue to move more or less in Proportion as they communicate more of their Force,

Arist. If Motion is lost after that Manner, it is found in one Body proportionally as it is lost in another. This seems plain.

Eud. Hence the Knowledge and natural Explanation of a Number of curious Facts.

Arist. Let us attempt to explain them according to your Principles.

Eud. 1. One is more fatigued by walking upon moving Sand, than upon dry Ground, or upon Pavement itself. Why?

Arist. One communicates much more Motion to the moving Sand because it yields, and because the greatest Part of the Grains of Sand receive their particular Motion, beside the common Motion. The more one communicates, the more one loses; the more is lost; the

Upon the general Rules of Motion. 113

the more one is exhausted; and the more one is exhausted, the more one is fatigued.

Eud. 2. A Cannon-Bullet ought then to be sooner stopp'd in the Air, than in Water.

Arist. Quite otherwise; it ought to stop, and does stop sooner in Water; the Water yields, and is divided indeed, but with more Difficulty; it must therefore give it more Force; the Bullet does give it more Force; and the more it gives, the more it loses.

Eud. 3. If the Bullet pass through the Air over a very large River, or a Pond, it falls down much sooner. What precipitates its Fall?

Arist. It is an Excess of Resistance in an Air more filled with Vapours, and more dense, which is divided with great Difficulty. The Bullet, in order to divide it, imparts more Motion; in Proportion as it imparts more, it loses more; proportionally as it loses more, it finds an End of it sooner.

Eud. 4. Suppose the Bullet encounter a Rampart of Earth, a Brick Wall, or a Sack of Wool, the Motion is sooner deadened than by the Stroke of a very hard and thick Wall.

Arist. In the Earth, Wool and Brick the Parts are sufficiently flexible, they give Place, bend, and are loosened pretty easily, to receive from the Bullet each their Quantity of proper Motion. These Quantities of proper Motion quickly equal the common Motion of the Bullet; and this is so much loss to it. The Bul-

114 CONVERSATION VIII.

let having in a short Time lost its Motion, is quickly deadened, and remains at Rest in the Earth, Brick or Wool. But should it encounter a thick Wall of very hard Stones, the Parts of these Stones are not sufficiently flexible, do not yield, nor bend, nor are loosened with Ease enough, so as each may receive its Quantity of particular Motion; they only receive a common Motion which does not at all equal that of the Bullet; and the Bullet recoils with that Force, which is left it.

Eud. 5. But the Bullet, which would be quickly deadened in the Brick, makes a Pannel fall from a Wall more hard and solid.

Arist. It does this, because it ought so to do according to the fourth Rule. In the Brick the Motion becomes peculiar in some Sort to the imperceptible Parts. From the imperceptible Parts of the Brick it passes into those of the Air and subtile Matter; and the whole Effort of the Bullet is, as it were, annihilated. But in the Pannel of a much harder Wall, the Motion of the Bullet does not become proper to the imperceptible Parts; it is almost wholly employed to displace the Pannel of the Wall. It does displace it, and makes a free Passage for the Enemy.

Eud. 6. The Cannon-Ball does not perplex you. But an Arrow, which presents its Point to the Resistance of the Air before it goes a great Way; whilst another Arrow, which presents its Side, falls down again almost immediately.

Upon the general Rules of Motion. 115

diately. These two Arrows may give you more Uneasiness than the Bullet.

Arist. Not at all. The Arrow, which presents only its Point to the Air, goes a long Way, because encountering but with little Air every Moment it communicates and loses little of its Motion. The other, which presents a much larger Surface, quickly falls again, because meeting with much more Air every Moment, it communicates and loses much more of its Force.

For the same Reason a Beam, whose Extremity cuts the Air, is more easily carried; and a Boat, which presents its Side to the anterior Air, is stopped with less Effort.

Eud. Hence the larger Surface a Body has in Regard of its Mass, the more of its Force it loses every Moment. As it strikes against more Parts of the *Medium* which it must cut through, it gives equal Quantities of Motion to more determined Parts; and the more it gives, the more it loses. But the smaller Bodies are, the larger Surface they have in Regard of their Mass. For divide a Globe into two Hemispheres, before the Division the two Hemispheres had only the Circumference of the Globe for their Surface, but after the Division they have for Surface, both this Circumference, and likewise two Planes: Therefore Bodies, the smaller they are, lose the more of their Force, *cæteris paribus*.

116 CONVERSATION VIII.

This being granted, I put into two equal Fuses the same Load of Powder, ten Shot into one, and into the other a Bullet whose Weight equals the ten Shot. Will the ten Shot go as far as the Ball?

Arist. No. The ten Shot being smaller, each in Particular, than the Ball, they have more Surface in Regard of their Mass; having more Surface, they will encounter more Obstacles; encountering more Obstacles, they will communicate more Force; communicating more Force, they will lose more; losing more Force, they will make less Way: Therefore they will not go so far as the Bullet.

Eud. But instead of Fuses, Bullet and Shot, I suppose two, *Jets d'Eau*. In one of them the Water runs off in Threads through a Number of small Pipes, and falls down again in Rain; in the other an equal Quantity of Water springs up by the same Passage in Form of a Cylinder. Which of the two springs highest?

Arist. The last; since having less Surface in Proportion to its Mass, it communicates every Moment, and loses less of its Force.

Eud. After this it is easy to comprehend why rugged Bodies move with greater Difficulty than such as are polished; because the first having more Surface on Account of their Inequalities, meet with more Obstacles, and communicate more of their Motion. But finally,

Upon the general Rules of Motion. 117

nally, whence proceeds that Facility in spherical Bodies to turn round upon their Center?

Arist. Finding no great Impediment to their circular Motion, they communicate but little of it. Hence a Whirligigg and a Top keep theirs a long Time; and turning about upon their Center, seem to sleep calmly, without any Fear of losing their Forces.

Eud. Here then, in a Word, are the four Rules of Motion, which all Bodies follow, as it were, with Emulation.

Rule I. A Body that is moved ought to continue in Motion, until some external and particular Cause determine it to rest.

Rule II. A Body that is moved describes, or tends to describe, a strait Line.

Rule III. A Body carried by different Impressions towards different Points, or which has divers Determinations, yields to them all in Proportion to their Forces.

Rule IV. Motion that is lost, is lost by Communication.

All these Rules are equally observed both in hard, elastic and soft Bodies.

Arist. But what is the Cause of the Hardness, Elasticity, and Softness of Bodies?

Eud. This is a difficult Subject which deserves to be thought on before one pretend to discourse of it.



CONVERSATION IX.

Upon the Hardness, Elasticity and Softness of Bodies.

Eud. WELL, *Aristus*, what is the Hardness † of Bodies according to your Judgment?

Arist. It is the Resistance of Bodies to the Division of their Parts. But whence this Resistance

† All Bodies that are perceived by our Senses, consist of very small Parts, no one of which is indivisible of itself; but all of them are in Respect to us: For all the Division we can make is only a Separation of Parts. When a great Force is required to make such a Division, a Body is said to be *hard*.

If the Parts yield more easily, and fall in by being pressed, such a Body is said to be *soft*.

But this great and lesser Force in the common Signification, determiné nothing; for a Body that is hard in Respect to one Man, seems soft to another.

Defin. 1. A Body is said to be *hard* in a Philosophical Sense, when its Parts do not alter their Situation with Regard to one another upon any Force impressed.

Defin. 2. A Body is said to be *soft*, in a Philosophical Sense, when its Parts yield inwards, and slip in upon one another, even though it may require a Blow with a Hammer to do it.

Defin. 3. A Body whose Parts yield to any Impression, and by yielding are easily moved, in Respect to each other, is called a *Fluid*.

All these Things depend upon the Cohesion of Parts, the closer that Cohesion is, the nearer a Body approaches to perfect Hardness.

But

On the Hardness, &c. of Bodies. 119

stance proceeds, and what occasions the Hardness of Bodies, I acknowledge I do not easily understand.

Eud.

But the Hardness of the smallest Parts does not differ from their Solidity, it is an essential Property of a Body, which is no more to be explained, than why a Body is extended, or a Mind thinks.

It is uncertain whether all Bodies consist of Parts that are equal and alike: And there are also several Things very difficult in Relation to the Cause of the Cohesion of the small Parts of Bodies.

It is a particular Law of Cohesion, that all the Parts have an *attractive Force*.

Defin. 4. By the Word *Attraction* I understand, *that Property by which two Bodies tend towards each other, without external Force.*

But that *Attraction* is subject to these Laws; *that it is very great in the very Contact of the Parts; and that it suddenly decreases, insomuch that it acts no more at the least sensible Distance; nay, at a greater Distance it is changed into a repellent Force, by which the Particles fly from each other.*

We see that in all Liquors all the Parts attract one another, from the spherical Figure that the Drops always have; and also because there is no Liquor whose Parts are not sticking to one another, which is evidently true even in *Mercury* itself. Besides, in all Liquids, two Drops, as soon as they touch one another ever so little, immediately run into one larger Drop. All which Things, as they also happen in liquified Metals, it follows, that the Parts of which they are compounded do attract one another, even when they are disjoined by the Motion of the Fire.

These Appearances do not depend upon the Pressure of the Air, because they also happen where there is no Air; neither do they depend upon the Pressure of any other Matter equally from all Sides; for though such a Pressure is able to keep the Drops to their spherical Figure, it can by no Means bring them to it at first.

Defin. 5. *Elasticity of Bodies*, namely, *that Property whereby they return to their former Figure, when it has been altered by any Force: This is easily deduced from what has been said: For if a compact Body be dented in without the Parts falling into that Dent, the Body will return to its former Figure, from the mutual Attraction of its Parts.*

Eud. Hear then my Sentiment upon that Head. Hard and sensible Bodies have their perceptible and imperceptible Parts. The first are compounded of the last. Both the one and the other have their Hardness; whence proceeds, at least in Part, the Hardness of sensible Bodies.

1. Whence proceeds the Hardness of the imperceptible Parts? From the relative Rest of their Particles, purposely preserved by the general Cause, or the Will of God, until some foreign and particular Cause come with a certain Degree of Force to divide them. The Hardness of the imperceptible Parts proceeds from this Principle, or from their own Nature, or from the Pressure of some subtile and fine Matter, which surrounds them. Now it does not proceed from the Nature of the im-

Now lest any one should imagine, because we do not give the Cause of the said Attraction and Repulsion, that they must be looked upon as *occult Qualities*: We say here with Sir *Isaac Newton*, "That we consider those Principles not as occult Qualities, which are supposed to arise from the specifick Forms of Things; but as universal Laws of Nature, by which the Things themselves are formed: For the Phænomena of Nature shew, that there are really such Principles, though it has not been yet explained what their Causes are. To affirm that the several Species of Things have occult specifick Qualities, by which they act with a certain Force, is just saying nothing. But from two or three Phænomena of Nature to deduce general Principles of Motion, and then explain in what Manner the Properties and Actions of all Things follow from those Principles, would be a great Progress made in Philosophy, though the Causes of those Principles should not yet be known". *Vide Gravesande's Elements*, B. I. c. 5.

perceptible

perceptible Parts; one sees no Hardness in their Idea, and the Particles yet more minute, of which they are compounded, are themselves perfectly indifferent as to their remaining, or not, near one another. Neither does it proceed from a more subtile and fine Matter which surrounds them. For, in short, it is probable that this subtile and fine Matter has its own Hardness: But whence should it have it? We must run up to Infinity. Besides, all the Particles of the imperceptible Parts, would, without any Difficulty, run horizontally upon one another, as one polished Marble upon another. The Hardness then of the imperceptible Parts proceeds from the relative Rest of their Particles, such as I have said. In short, there can be no other Principle of Hardness, and without Hardness there can be no Universe.

2. Whence proceeds the Hardness of the sensible Parts? From the firm, solid and unequal Texture of the imperceptible Parts. The imperceptible Parts inclosed after a Thousand Manners, and crowded into one another, make the sensible Parts; the Hardness of the imperceptible Parts, inclosed and intangled after this Fashion, obstruct their Division: Hence the Hardness of the sensible Parts, composed of a Texture of imperceptible Parts.

3. Lastly, the perceptible and hard Parts having divers Figures, and being interwoven with one another, cannot be divided without the breaking of an infinite Number of small, imperceptible

perceptible and hard Parts. From the Concatenation of these sensible Parts, seconded by the fluid or subtile Matter, and Air which surround them, pressing them on all Sides toward a common Center, proceeds the Hardness of sensible Bodies.

Arist. According to your Sentiment the Hardness of the imperceptible Parts proceeds immediately from the relative Rest of their Particles, the Hardness of the sensible Parts from the Texture of the imperceptible, and the Hardness of entire Bodies from the Concatenation of the sensible Parts and Pressure of the Fluid which surround them. This is to explain, after a probable Manner, a Thing difficult to comprehend; and this makes me impatient to know what you think of the Elasticity of Bodies.

Eud. The Action of foreign Force, the Effort of the Hand for Example, bends a Plate of Steel, compresses a Foot-Ball, bends a Bow, &c. Should this Action cease, the Bodies resume of themselves, as it were, their former Figure; and that which makes them resume it as of themselves, is what they call the Spring, or elastic Force. What then is the Elasticity of Bodies? It is that which makes them resume as of themselves that Figure which some foreign Force had taken from them.

Arist. But the Figure which folded, compressed, and bended Bodies, seem to resume of them-

themselves, do they really resume it of themselves?

Eud. No; for being of themselves only a Portion of Extension, they are no less indifferent to such or such a Figure, than to such or such a Direction; they are neither for a square Figure, nor for a round one; the Figure which Compression gives them fits and accomodates them, as well as that which it takes away from them.

Arist. Therefore some external Cause must restore to them, and oblige them to resume the Figure which they have lost by the Pressure. But what is this external Cause? The subtile Matter, without doubt.

Eud. It is the subtile Matter or the Air, as we have observed already. It is an imperceptible Body; it is, I say, a Body; for it is something that strikes, touches and modifies: And this Body is imperceptible; the Senses do not perceive it. But it is not the Air, the Air itself has its own Spring, as Experience shews. In a Foot-Ball the Air is compressed an hundred Times more than in its natural State. It resumes its former Figure, and it resumes it only because it is restored to it: For it has no Interest to resume it, it is very indifferent to it. Therefore the subtile Matter is the external Cause which restores to compressed Bodies, that Figure which the Pressure had taken from them. Not but the Air, which has its Spring, and which finds itself shut up in the contracted

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ed Pores of other Bodies bended or compressed, contributes immediately, by Virtue of its Spring, to restore them to their former Figure: But it is the subtile Matter which sets this Spring a-going.

Arist. But how does subtile Matter restore to Bodies the Figure which they had lost?

Eud. In Compression the Parts are bowed, the Pores of the Concave Surface are contracted, and the Pores of the convex Surface are enlarged. The subtile Matter, which is in a violent Agitation, passing from the last into the first accelerates its Motion, to the End that what passes through the larges Pores, may pass in equal Times through those which are more strait; this Acceleration of Motion opens and dilates the contracted Pores, both of the Air, if any be met with, and also of the Body which contains it. The contracted Pores cannot be dilated without the Contraction of the enlarged ones; those cannot be dilated, nor these contracted, without the compressed Bodies being restored to their former State; Thus the subtile Matter restores them to their former Figure, much after the same Manner as the Humidity imbibed into an extended Rope, but somewhat crooked, makes it strait; or as Water that is filtred in a compressed Sponge, does extend and restore it to its natural Situation.

The subtile Matter may contribute farther to re-establish compressed and curved Bodies

in their first State, by flowing from one Extremity to another; as the Air, which we cause to enter with some Effort into a flexible and crooked Pipe, makes it change its Figure, and streightens it.

Arist. I conceive perfectly well, and approve your Sentiment. The Action of the subtile Matter, which runs with some Acceleration of Motion into the Pores contracted by Compression, is the external Cause which makes the Spring play, or unbends it. But beside the Action of the subtile Matter, must there not moreover be an internal Cause, or some particular Disposition on the Part of the Body?

Eud. That the Body may be rendered elastic, there must be a certain Flexibility of Parts, a certain Stiffness or Hardness, and Pores neither too small, nor too large. There must be 1. a certain Flexibility of Parts; otherwise the Body cannot be compressed, nor consequently dilated. 2. A certain Stiffness or Hardness; without this the subtile Matter making new Passages for itself too freely, would neither open nor enlarge the contracted Pores. 3. Pores which are not too small, to give Access to the Action of the subtile Matter. 4. Lastly, Pores which are not too large, lest the subtile Matter pass through without making any Effort to enlarge them.

Arist. Your Sentiment concerning Elasticity is perfectly agreeable to the Idea which I had formed to my self in reading *M. Descartes*,
and

and *M. Robault*; and nothing, I think, is more happy for explaining the surprizing Effects of Elasticity, and whatever relates to it.

Eud. Let us make a Trial of it. The Force of Elasticity is acquired, augmented, diminished and lost. Whence proceed these Changes, which are to Philosophers so many Species of Miracles of Nature?

Arist. 1. If the Pores, which were too large, are contracted, or those which were too small are enlarged, the subtile Matter begins to pass with some Violence through the one and the other; its Action dilates and extends them; and thus you have some acquired Force of Elasticity.

2. Let the contracted Pores be contracted yet more, or let the enlarged Pores be still more enlarged, there passes more subtile Matter through the last, and it passes with a greater Effort through the first, and thus the Spring is augmented.

3. Are the Pores a little too much contracted, or too much enlarged? There passes too little subtile Matter through the one, and it passes too easily through the other; its Effort is abated, and thus the Spring is diminished.

4. Does the Excess of Contraction, or of Dilatation, proceed to a certain Point? The subtile Matter finds no more Passage, or at least it passes without Effort, without dilating or extending

tending the Interstices; and thus the Spring is lost.

Eud. After this one may presently comprehend why Lead, soft Wax, and soft Bodies, have so little Elasticity.

Arist. That is because those Bodies having too flexible Parts, or too great Pores, give too free a Passage to the subtile Matter.

Eud. But Steel, which has never been tempered, has however stiff Parts, and yet but little Spring.

Arist. This Steel has little Spring, because the Corpuscles of Fire, for want of tempering, have been too long Time agitated in its Pores, and have too much enlarged them by the Continuance of their Agitation.

Eud. By a contrary Reason tempered Steel ought to have much more Elasticity.

Arist. Without doubt, because the Liquor has contracted its Pores, and extinguished the Corpuscles of Fire.

Eud. But why does the very tempering itself give little Elasticity to Steel that is too hot?

Arist. Because then the Excess of Heat, notwithstanding the Liquor which cools the Steel, renders its Pores something too large.

End. Beat the Steel, and its Spring is improved.

Arist. One sees the Reason of that immediately, the Pores which were too large are contracted.

Eud.

128 CONVERSATION IX.

Eud. But why does the Steel lose this acquired Force so quickly in a Fire too violent?

Arist. Because the excessive Agitation of the Corpuscles of Fire enlarges its Pores too much. Thus in order to give Elasticity to the Steel in the tempering, there must be a certain Degree of Heat.

Eud. Thus the Elasticity of Steel seems to be handsomely explained. But why has green Wood so much Elasticity, in Comparison of Wood that is dry and Worm-eaten?

Arist. Because the subtile Matter by Virtue of its passing through the Interstices of Wood too dry and Worm-eaten, has therein made it-self more free Passages than in the green Wood, and by much too free. It finds in the Pores of the green Wood a Liquor, Juices and Obstacles, which it does not meet with in that which is old and Worm-eaten.

Eud. I see what you are about to say of a Bow, which unbends, as it were, of itself, or loses its Elasticity, by Reason of its having been bended too long a Time.

Arist. When the Bow is bended, the Pores which are toward the convex Surface are enlarged, and those which are toward the concave Surface are contracted. Leave the Bow at Liberty to unbend itself: The subtile Matter which glides through the large Pores accelerates its Motion, insinuates itself, and flows with Violence into the smaller ones. These are dilated, and those contracted proportionally;

ly; the Bow is unbended. Has it been too long Time bended? The subtile Matter, by Means of its striking against the closed Pores, or against the solid Parts, has made itself a free Passage. From the Time that it passes freely, it makes no more Effort to enlarge the Interstices. Hence no more Spring, and the Bow refuses to shoot the Arrow.

Eud. The Spring of the Air ought, I think, to be finally lost, or diminished at least as well as that of a bended Bow. However it is neither lost nor diminished. A Portion of Air extraordinarily compressed, appeared still to have the same Force of Elasticity after 16 Years Pressure^r.

Arist. The Elasticity* of the Air ought not to be changed like that of mixed Bodies: For
1. The Air being a more simple Body has not so many Interstices, it does not furnish so many new Passages to the subtile Matter.

2. As the Pores of the Air are very strait, the subtile Matter does not pass through them charged with foreign Corpuscles, which contribute very much to cause an Alteration in more gross Bodies.

3. The Particles of the compressed Air being interwoven with one another, and straitly united, afford less Access to the subtile Matter, and the subtile Matter makes itself new Passages with greater Difficulty. Hence the Spring

^r Hist. de l'Acad. 1695. p. 368. * See CONVERSAT. XXIII.

130 CONVERSATION IX.

of the Air ought to be preserved a longer Time. It is actually preserved a longer Time, and after 16 Years Compression in a kind of Fusee, it is still found in a Condition to drive out a Ball with Violence, and convey Death to 30 Paces Distance.

Eud. When one knows thus far the Properties of Elasticity, one knows the secret Principle which animates a Watch, if I may speak so.

Arist. This secret Principle is the Spring of a thin Plate of Steel rolled up upon itself in the Form of a spiral Line, and inclosed in the Barrel of the Watch. This Plate has unequal Pores. Those of the concave Surface are less, as in the bent Bow. Those of the convex Surface are bigger. The subtile Matter which runs easily in the bigger Pores, meeting with Obstacles in the less, dashes against and strikes them, by its repeated Blows opens a Passage for itself, and accelerates its Motion. This redoubled Motion separates the opposite Parts of the Pores, and dilates them, and thus gradually the Plate of Steel is unwound. The Effort of the Matter which endeavours to flow in a right Line, according to the second Rule, from one Extremity of the Plate to another, assists the Explication. The small Chain, which penetrates into the Barrel, receives its Motion from the Spring that is unfolded, and communicates it to the Wheels of the Watch. The Hand of the Watch, which is fixed to the Axle-tree of the Wheel that moves most slowly,

goes

goes about also after an imperceptible Manner, and by its insensible Motion, marks out the divers Moments of that Life, which passes away as imperceptibly as the Motion of the Hand itself.

Eud. I am delighted to see you discover how Nature produces the astonishing Effects of Elasticity. But let us at last say something of the Softness of Bodies.

Arift. I always find a new Pleasure in hearing you upon a new Subject.

Eud. They call soft Bodies, Bodies which are easily compressed without endeavouring, at least in a visible Manner, to resume their former Figure. What then is the Softness of Bodies? The Facility which their Parts have to be loosed from, and to move upon one another, without any sensible Effort to restore themselves to their former Situation. Whence finally proceeds this Facility, this particular Disposition? From the polished Surface of the insensible Parts, and from the Action of the subtile Matter, which running through a Thousand and Thousand Places in the soft Bodies, moves, agitates and shake their Parts, so that the moved, shaken and agitated Parts which are attached to one another by very small Surfaces, can be broken, loosed, and slide upon one another; without any Thing obliging them to resume their former Situation; because if the subtile Matter find some Passages stopped, it finds others free, or makes

K 2

itself

132. CONVERSATION IX.

itself some new ones without any Obstruction. Hence soft Wax immediately assumes under the Hand, and retains indifferently all Sorts of Figures; and you may see the Figures of Tygers and Lions upon Confections equally sweet, soft and delicious.

Let us conclude our Conversation with an Experiment. Run two Pins into the two Extremities of a Stick about three Foot long, dry and as large as your Arm. Place two Glasses half full of Water upon two Tables of equal Height, about three Foot distant from one another. Put the Stick in an horizontal Situation, so that the two Pins may rest upon the Brims of the two Glasses. Strike the Middle of the Stick violently, and you may see it broken cleanly notwithstanding its Bigness, without breaking the Glasses, however brittle they be. If the two Extremities of the Stick rested upon two Threads hung up perpendicularly, we might see the like Effect. Why is the Stick broken?

Arist. The Middle of the Stick, the Point struck is compressed, and immediately receives a sudden Impression of the Blow. It passes to the Extremities but successively, and by a great Number of Parts which receive it the one after the other, and the one from the other, like so many elastick Bodies ranged upon the same Line. Hence it is that the Middle, the Point struck yields immediately, and before the rest: And thus the Stick is broken.

It

It is not broken without observing punctually the Laws of Nature. It takes the most easie Course. To avoid breaking, notwithstanding the Effort of the Blow, it must have yielded and descended with the same Velocity, or much the same, in all its Length. But in order to yield at that Rate, more Force must have been used. It must have driven away with the same Velocity a Mass of Air as large and long as the Stick; which would have required more Force. The Force ought to increase in Proportion, when a greater Mass is to be moved with the same Velocity.

Eud. But why are not the Glasses broken? Why do not the two Threads that are suspended break asunder?

Arist. When the violent, but successive Impression reaches the two Extremities of the Stick, they are elevated both the one and the other, in Proportion as the Middle yields and descends in the Fracture; and this Elevation removes from the Glasses or suspended Threads that Impression which might break in Pieces the one, and break asunder the other.

Eud. All Bodies, hard, elastic and soft, often strike against one another; and in this they always observe some particular Rules, which well deserve a particular Conversation.



CONVERSATION X.

Upon the Rules of the Percussion of hard Bodies.

Arist. **P**RAY, *Eudoxus*, endeavour to make me understand those Laws of Nature, so exactly observed in the Percussion of Bodies,

Eud. In order to discover and conceive those Laws or Rules the more easily:

1. Let us suppose that hard Bodies are perfectly hard, elastick Bodies perfectly elastick, and soft Bodies perfectly soft. I call perfectly hard Bodies, Bodies incapable of changing Figure by a Stroke. I call those perfectly elastick Bodies, in which the Force of unbending is equal to that of bending. By perfectly soft Bodies I understand, Bodies which are flatted by the Stroke without restoring themselves in any Manner.

2. Let us examine the Stroke of two Bodies of the same Species, of two ivory Billiard-Balls. Let us suppose that the Stroke of those two Bodies happens directly, and in a free *Medium*, or such as gives no Obstacle to their Motion,

On the Percussion of Bodies. 135

Motion, and which takes nothing from their Force.

3. Let us take Notice that in the Stroke the Force of Percussion answers to the Resistance; since a Body moved has no Liberty, no Aim, and the Question is about its making Way for itself to continue in Motion according to the same Direction.

4. Lastly let us consider the Stroke of Bodies in three different Cases; 1. When a Body moved strikes against a Body in Rest. 2. When a Body that has more Velocity overtakes a slower Body that goes before it. 3. When two Bodies meet one another with opposite Forces equal or unequal.

Arist. What ought to happen in those three Cases, to hard, elastick, and soft Bodies?

Eud. Let us speak first of the Stroke of hard Bodies,

RULE I.

If a Body in Motion strike another at Rest, it puts it into Motion.

The Body struck is moved after the Stroke, or else resists the Force which strikes it: But it does not resist this Force neither of itself, since of itself it has no Efficacy, and is in an entire Indifferency as to Motion or Rest; nor by any Property of Rest, since Rest which is not susceptible of more or less is incapable of

136 CONVERSATION X.

resisting Motion, whose Velocity is susceptible of Degrees multiplied *in infinitum*: Consequently the Body struck is moved after the Stroke. Therefore a Body moved, which strikes another in Rest, puts it into Motion.

RULE II.

A Body in Motion, which moves another at Rest, imparts to it of its Force in Proportion to the two Masses.

A Body moved, which strikes a Body in Rest, imparts to it so much of its Force precisely as is necessary to remove the Obstacle which proceeds from the Impenetrability of the Body struck, and in vain would it impart more or less. Now to remove this Obstacle there must be imparted, and it is sufficient to impart a Force to the Body at Rest, in Proportion to the two Masses. Then the equal and determinate Parts of the two Bodies, having equal Forces, ought to go both together with the same Direction and with equal Velocities, without the one staying or retarding the Motion of the other. Therefore a Body moved, which moves a Body in Rest, imparts a Force to it in Proportion to the two Masses.

In a Word, separate the two Bodies into equal Parts, and divide the Motion into as many equal Parts; then impart to the equal Parts of the two Bodies equal Quantities of Motion:
Such

On the Percussion of Bodies. 137

Such is the Distribution of Motion in the Stroke of a Body in Rest. Hence if the Body which strikes it is equal in Mass, it imparts one half of its Force. Is it subduple? It imparts two Thirds. Is it double? It imparts one Third, &c.

R U L E III.

If a Body which has more Velocity, strike another that goes before it, it will distribute its Excess in Proportion to the two Masses; and after the Stroke they will both go together with the same Velocity.

If the first impinged against the second in Rest, with a Quantity of Motion equal to its Excess of Velocity, it would distribute this Quantity of Motion in Proportion to the two Masses by the second Rule. But this is as if it found it in Rest with a Quantity of Motion equal to its Excess of Velocity: For there is no Regard to be had in the Stroke to the common Velocity, or that which is found alike in both Bodies. It is nothing in Regard of the Percussion, because it is so far from contributing towards it, that it snatches away one Body from the Stroke of another: Therefore, &c.

R U L E

RULE IV.

If two Bodies strike one another with contrary and equal Forces, what will happen? They will be reflected with the same Forces.

They must be reflected after this Manner, or they must lose their Forces in the Stroke; in short, they will not go forward, since having opposite and equal Forces, they can neither overcome nor yield: Now they will not lose their Force by the fourth general Rule, since they will communicate none of it: To communicate it, is to prevail; and neither the one nor the other will be victorious. Therefore they will be reflected with the same Forces.

RULE V.

If two Bodies strike one another with contrary Directions and unequal Forces, they will go after the Stroke toward the same Place, according to the Direction of the stronger.

The stronger will continue to move in the same Direction, since being stronger it ought to prevail, and if it communicate of its Excess of Force, it will only distribute it in Proportion to the two Masses to remove all Obstacles to its Direction. The weaker will re-
turn

turn back again. In a Word, it ought to go forward, or rest, or be reflected. It will not go forward; for being the weaker, it cannot overcome the stronger, which opposes to it its Impenetrability. It will not rest, since by the same Reason it will communicate nothing, and consequently will lose nothing of its Force. Therefore it must return back. Now the stronger cannot move with the same Direction, and the weaker be reflected after the Stroke, but that they must both go toward the same Place, following the Direction of the stronger: Therefore, &c.

Arist. But if the weaker have precisely so much Velocity before the Stroke as the stronger has, what ought to happen?

Eud. The weaker ought to be reflected with the same Velocity precisely, since it is sufficient and necessary for removing all Obstacle to the Motion of the stronger.

Arist. What if the Velocity of the weaker do not equal the Velocity of the stronger before the Stroke?

Eud. The weaker will have more Velocity after the Stroke, than it had before it: It must have at least as much as the stronger, that it may go before it; otherwise it would resist by its impenetrability, and would be the weaker without being so.

Arist. But finally, what if the weaker have more Velocity before the Stroke?

Eud.

140 CONVERSATION X.

Eud. It will preserve the same Excess after the Stroke; for being the weaker, it will impart nothing of its Force.

Arist. These Rules, *Eudoxus*, are clear and plausible, and I seem to understand them.

Let us suppose that a Body moved strikes a Body at rest; the first I call *B*, and the second *C*. *B* being equal, if it has 2 Degrees of Motion, it communicates 1. *B* being double, if it has 3, it gives away 1. *B* being Subduple, if it has 3, it imparts 2.

Let us now suppose that *B* overtakes *C*, which goes before it. If *B* being equal has 3 Degrees of Motion, and *C* 1, *B* will communicate 1. If *B* being double has 5, and *C* 1, *B* will communicate 1. If *B* being Subduple has 5, and *C* 1, *B* will give away 3. Lastly let us suppose that both *B* and *C* impinge against one another. If *B* and *C* have each 6 Degrees of Motion, they will be reflected each with 6 Degrees. If *B* being equal has 4, and *C* 2, *B* will communicate 1, and *C* will return back with 3. If *B* being double has 4, and *C* 2, *B* will preserve its 4, and *C* ought to be reflected with 2. If *B* being double has 10, and *C* 2, *B* will impart 2, and *C* ought to return with 4. Has *B* 4 Degrees of Mass and 1 of Velocity, *C* 1 Degree of Mass and 2 of Velocity? *C* ought to be reflected with its 2 Degrees of Velocity; since being the weaker, notwithstanding its Excess
of

On the Percussion, &c. of Bodies. 141

of Velocity, it can communicate nothing of its Force.

Eud, Let us come to the Rules of Percussion of elastic Bodies, or rather, *Aristus*, do you go and divert your self by playing at Billiards with *Eugene*. You will play like a Philosopher; and the Reflections which you will make upon the Stroke of the two Balls, will afford you some Light into what we have to say.



CONVERSATION XI.

Upon the Percussion of elastic Bodies.

Arist. **G**AMING itself may be a Lesson. The Stroke of the two Billiard-Balls presents to the Eye of a Philosopher, who searches after Truth even in his Sports, Wonders which doubly increase the Desire I have to hear you upon the Percussion of elastic || Bodies.

|| We know no Bodies perfectly elastick; in different Bodies, the Force by which the Parts return to their former Figure is very unequal; for which Reason we can give general Rules only concerning perfect Elasticity; the nearer Bodies approach to this Elasticity, the more exactly will their Motion agree with these Rules.

Eud.

Eud. Let us begin with some Observations.

1. Elasticity is the Force which makes a Body changed as to its Figure, resume it as of itself. In order to resume it there must be a Force equal to that which changed it. Therefore the Force by which an elastic Body is restored, is equal to that which changed, flattened, or pressed it in.

2. When an elastic Body restores itself, it repels with all its Force the Body which struck it. Therefore it thrusts it back with a Force equal to that which struck it; therefore it endeavours to restore it its former Velocity, but with an opposite Direction.

3. Here I distinguish two Forces, or two Motions, the one direct, the other elastic. I call the direct Motion, that by which an elastic Body strikes another at first. I call the elastic Motion, that which proceeds from the Spring, and by which a Body flattened in the Stroke resumes the Figure which it lost.

4. In two Bodies, which are restored after the Stroke, the two elastic Motions being contrary, they are reflected by one another toward opposite Parts. For which Reason in a Body, which strikes and communicates its direct Motion, the elastic Motion is contrary to the direct Motion, which this Body preserves; in the Body struck, which receives direct Motion from the other, the elastic Motion favours the direct Motion.

Finally,

On the Percussion, &c. of Bodies, 143

Finally, let us give two Balls, two elastic Bodies, the Names of *B* and *C*. These Names express nothing useless, and yet are as significant as the most harmonious and comprehensive Names.

R U L E I.

*B strikes C equal and at rest: What happens?
In this Hypothesis, C being struck, is moved
in its Turn with as much Force as B had be-
fore the Stroke, and B rests.*

1. *C* being struck moves with as much Force, as *B* had before the Stroke. *C* cannot receive from *B* the half of its direct Motion, being doubled by the Power of the Spring, without moving with as much Force as *B* had before the Stroke. Now *C* being equal and at Rest, receives from *B* the half of its direct Motion, in order to remove all Obstacle, by the second Rule of hard Bodies; and this half of the Motion is doubled by the Force of the Spring, since the elastic Motion answers to the Compression, the Compression to the Percussion, and the Percussion to the direct Motion communicated in the Stroke, and the elastic Motion in the Body struck, seconds the direct Motion. Therefore, &c.

2. *B* rests after the Stroke. A Body which unites two equal and contrary Forces is stoppt and rests, because it cannot comply with both, nor yield to the one rather than the other,
and

and because those two Forces are lost in the imperceptible Parts, or are insensibly diffused into the Air. Now *B* reunites two equal and contrary Forces, namely, the half of the direct Force, and an equal and opposite elastic Force: For the elastic Force of the Body which strikes, is reflected by the elastic Force of the other, with a Direction contrary to that of the direct Force. Therefore *B* rests after the Stroke, so that the Truth of the Rule is obvious to the Eye.

Arist. Consequently if *B* is moved before the Stroke with six Degrees of Force, *C* will have six after the Stroke, three of the direct Force, and three of the elastic Force; and *B* in its Turn will remain without Motion.

I think I apprehend in this Principle, *Eudoxus*, the Reason of a pretty singular Fact. Upon a Plane, and upon a strait Line, I range five or six Balls equal and contiguous: One Ball, which singly strikes the first of these ranged Balls, makes the last precisely to move away. If two Balls which touch one another, go together to strike the first, you may see the two last move away. Three of them make three to move away, &c. Why? The Ball, which goes alone to strike the first of the ranged Balls, bestows on it the half of its Force doubled by the Efficacy of the Spring, loses the rest by the Opposition of its own elastic Force reflected by the Action of the Spring of the Ball that is struck, and ceases to

move,

On the Percussion, &c. of Bodies. 145

move; after the same Manner as *B* which strikes *C* equal, and at Rest. The first Ball being struck, strikes the second after the same Manner, and also loses its Force, &c. The last alone, which meets with no Ball in its Way, receives the whole Impression without communicating or losing it, and moves away alone. When two go to strike, their Impressions are successive. At first the Action of the former passes as far as the last of the ranged Balls; and makes it run off; the Action of the other immediately follows, and makes the last but one pass off to accompany the last, &c.

RULE II.

Eud. If B being greater strike C that is less and at Rest, they will both go after the Stroke toward the same Place.

They will go, I say, with the same Direction after the Stroke, if *B* preserves its direct Force; but *B*, no doubt, will preserve it. 'Tis true it will lose what passes into *C*, and the contrary elastic Force ought to destroy as much again: But as it will not give to *C* the half of its Force being greater than *C*, but will only give precisely in Proportion to the two Masses, and as the Force of the Spring will destroy no more of it than is communicated, since it answers to the Force communicated; it ought to

146 CONVERSATION XI.

reserve to itself some Degrees in order to follow the Traces of *C*.

B being double, *e. g.* strikes, with a Force of six Degrees, *C* being Subduple and at Rest; what will happen?

Arist. According to your Principle *B* will impart two Degrees of Force to *C*; these two Degrees will be doubled by the Force of its Spring; *B* which will lose these two Degrees, ought moreover to lose other two by the contrary Force of its Spring: Therefore *B* and *C* will go toward the same Place, *B* with two Degrees, and *C* with four.

RULE III.

Eud. *B* goes from the West to strike *C*, being greater and at Rest; what happens? *B* is thrust back toward the West.

It must be thrust back toward the West, if its elastic Force be stronger than the direct Force which remains to it: But its elastic Force is stronger. For the elastic Force answers to the Motion communicated in the Stroke, and this Motion exceeds that which remains in *B*. *B* being the less ought to communicate more than a half of its Force, since it communicates of it in Proportion to the two Masses. Therefore if *B* go to strike *C*, being greater and at Rest, it ought to be reflected.

Let

On the Percussion, &c. of Bodies. 147

Let us suppose *B* a Subduple; it has six Degrees of Force, and goes to strike *C*.

Arist. *B* will recoil with two Degrees. For at first it will impart four according to the Proportion of the Masses: Consequently the Motion of the Spring, which tends to drive it back, will be of four Degrees. Of those four Degrees two will be destroyed by the two opposite Degrees of direct Motion, which it retains. There will remain in *B* two Degrees of elastic Force: Therefore it ought to return with two Degrees.

RULE IV.

Eud. If *C* go before, and *B* being equal, but having more Velocity meet with it, they will both continue to go forward with the same Direction, but will make an Exchange of Velocity.

1. They will continue to go forward; for they will lose nothing of their common Velocity, since it is no Way employed in the Stroke. If *B* and *C* have each two Degrees of common Velocity, the two Degrees of *C* will pass into two Degrees of *B*.

2. They will make an Exchange of Velocity, if after the Stroke *B* only retains its common Velocity, and *C* have, beside its common Velocity, a Velocity equal to the Excess which was found in *B* before the Stroke: Now, 1.

L 2

B will

148 CONVERSATION XI.

B will only preserve its common Velocity; for it will give an half of its Excess of Velocity to remove the Obstacle of Impenetrability, and will lose the other half by the contrary Force of its Spring. 2. *C*, beside its common Velocity, ought to have a Velocity equal to the Excess which was found in *B* before the Stroke, since it will receive the half of this Excess doubled by the Force of its Spring. Therefore, if *C*, &c.

This being granted; if *C* precede with four Degrees of Velocity, and *B* follow with 12 Degrees, what will happen?

Arist. *B* will immediately communicate four Degrees to *C*, in order to remove the Obstacle of Impenetrability, and these four Degrees will be doubled by the Spring. Consequently *C*, which according to the Proposition had four before the Stroke, will have 12 after the Stroke. Of the eight which remain to *B*, after it has given away four, it will lose four destroyed by the contrary Force of its Spring. Therefore *B*, which had 12 before the Stroke, will retain but four; and *C*, which had only four, will have 12 after the Stroke: Therefore they will continue to move with the same Direction, but with an Exchange of Velocity.

RULE

R U L E V.

Eud. *If B and C strike one another with contrary Directions and equal Forces, they will be repelled with the same Forces.*

They will be thrust back and reflected with the same Forces, if the Efficacy of the Spring restore them, after the Stroke, the Forces which they shall have lost in the Stroke by the Compression; for they will not move forward after the Stroke, since they are impenetrable, and one cannot overcome the other, having precisely equal Forces. But the Efficacy of the Spring will restore them the Forces which they shall lose by the Compression in the Stroke, since this Efficacy answers to the Compression, as the Compression answers to the Force employed and communicated in the Stroke. Therefore if *B* and *C* strike one another with contrary Directions and equal Forces, they will recoil with the same Forces.

R U L E VI.

If B and C having equal Masses strike against one another with unequal Forces, they will return interchanging their Forces,

For 1. They will lose their common Forces in the Stroke by the Compression or flattening;

L 3

but

but the Spring ought to restore them with contrary Directions. 2. The stronger will give the half of its Excess to the weaker, in which the Force of the Spring will double it, while it will destroy the other half in the stronger. Therefore if *B* and *C*, &c.

Let *B* come with six Degrees of Force, and *C* with two.

Arist. *C* ought to be reflected with six Degrees, and *B* with two; for they will lose by the Stroke, each two Degrees of common Force; but the Spring will restore them with contrary Directions. *B* will communicate two Degrees of the four of its Excess. It will lose the other two by the contrary Force of the Spring. Consequently it will have two precisely to return back. Beside its two Degrees of common Force, *C* will receive two by Communication, and these two will be doubled by its Spring: Therefore *C* ought to return with six Degrees of Force, and *B* with two.

But if *B* and *C* strike one another with equal Velocities, having unequal Masses?

Eud. 1. In this Hypothesis the less will always recoil: For being the weaker it will strike with all its Force, and will lose it all in the Stroke; but the Spring will restore it to it for driving it back. Moreover it will share in the Excess of the stronger. Therefore it will always recoil.

2. The greater will sometimes cease its Motion.

It

On the Percussion, &c. of Bodies. 151

It cannot have, after the Stroke, as much direct Force as elastic, without resisting; two internal equal and contrary Forces are null. But the greater will sometimes have, after the Stroke, as much direct Force as elastic. Let us suppose that *B* being triple comes with six Degrees of Velocity, and *C* with six. In this Hypothesis *B* ought to have, after the Stroke, a direct Force, and an elastic one, equal. For *B* having six Degrees of Velocity, and three of Mass, has 18 Degrees of Force, since the Force is the Product of the Mass by the Velocity. Of the 18 it will lose six common, which the Spring will restore it to make it recoil. Of the 12 which remain it will communicate three; for being triple it will give it a fourth Part of its Force. There remain nine. Of these nine Degrees it will lose three, which are destroyed by the contrary elastic Force, which answers to the Force communicated: Therefore it will have six Degrees of direct Force, and as we said just now, six Degrees of contrary elastic Force. Therefore the greater will sometimes have as much direct, as elastic Force; therefore after the Stroke it will unite two equal and contrary Forces; therefore it will rest sometimes.

3. *Sometimes the greater will recoil.*

When the elastic Force prevails over the direct, the Body must recoil, since that is contrary to this. But the elastic Force will sometimes prevail. Let us suppose in *B* five De-

degrees of Mass, and four of Velocity; in *C* three Degrees of Mass, and four of Velocity. The elastic Force will be predominant in *B*, if it retain precisely ten Degrees of elastic Force to rebound: But it will precisely retain 10 for recoiling. For *B* having five Degrees of Mass, and four of Velocity, has 20 Degrees of Force; *C* having three Degrees of Mass and four of Velocity, has 12 Degrees of Force. Therefore *B* will immediately lose 12 Degrees of common Force in the Stroke, since by these 12 Degrees it will impinge against a contrary Force of 12 Degrees; but the Spring will restore them. Of its Excess of eight Degrees, which will remain after the Loss of 12, it will give three to *C*, in Proportion to its Mass; and five remain. The elastic Force for recoiling, answers to the Force communicated or lost in the Stroke: Therefore it will be 15 Degrees. But *B* retains still five Degrees of direct Force, which it ought to lose by destroying five Degrees of the elastic: Therefore *B* will retain precisely 10 Degrees for recoiling. Therefore sometimes the greater will be reflected.

4. *Sometimes the greater will continue after the Stroke to follow the same Direction.*

For sometimes after the Stroke, its direct Force will be greater than its elastic. Let us suppose in *B* five Degrees of Mass, and three of Velocity, and in *C* one Degree of Mass and three of Velocity: *B* will retain five Degrees
of

On the Percussion, &c. of Bodies. 153

of effectual Force for advancing. In short, *B* having five Degrees of Mass and three of Velocity, it has 15 Degrees of Force; *C* having one Degree of Mass and three of Velocity, it has three Degrees of Force. Of the 15 Degrees of direct Force *B* will immediately lose three by the encountering of the three Degrees of *C*, but which will be restored to it; of the 12 remaining it will give two to *C*; for being quintuple it will communicate the sixth Part of its Excess; 10 remain. Of these 10 it will lose five by the contrary Force of Elasticity, since it answers to the Force destroyed or communicated: Therefore it will retain five in order to move forwards.

Therefore if *B* and *C* strike one another with equal Velocities, having unequal Masses, the less will always rebound: Sometimes the greater will rest; sometimes it will recoil; and sometimes it will continue to follow the same Direction after the Stroke.

By the Help of these Lights one may enter into a more exact Detail. You will explain to me, *Aristus*, at your Leisure the Rules which ought to be observed in the Percussion of soft Bodies.

CONVER.



CONVERSATION XII.

Upon the Percussion of soft Bodies.

Eud. **W**ILL you discover to me, *Aristus*, those Secrets which Nature has imparted to you?

Arist. When one comprehends the Rules observed in the Percussion of hard and elastic Bodies, it is easie to understand those which ought to be followed by Bodies that are soft.

RULE I.

If B strike C at Rest, it will give it some of its Force, in order to make itself a free Passage.

Since *C* will not resist either by itself, being very indifferent to Motion or Rest; nor by its Rest: Rest makes no Resistance to Motion, by the first Rule of hard Bodies.

RULE

R U L E II.

B ought to impart Motion to C at Rest, in Proportion to the two Masses.

For, in a Word, it will impart precisely so much as is necessary to make itself a free Passage, if it communicate neither more nor less, it must impart it in Proportion to the two Masses; the half if *C* is equal; the third Part, if it is Subduple; and two thirds, if it is double: Then will they go with the same Velocity, without any Obstacle. Therefore, &c.

R U L E III.

If B overtakes C, which goes before, B will divide the Excess of its Force with C in Proportion to their Masses.

In short, by this Excess *B* ought to strike *C*, as if it were at Rest: No Regard must be had in the Stroke, to the common Motion of the two Bodies. By this Motion the one Body runs from the other; this Motion is useless with Regard to the Stroke: Now if *B* found *C* at Rest with its Excess of Force, it would communicate it in Proportion to the two Masses: Therefore if *B* overtake *C*, which goes before, &c.

R U L E

156 CONVERSATION XII.

RULE IV.

If B and C strike one another with equal Forces, they will remain at Rest after the Stroke.

They must stop if they lose their Forces in the Stroke, without having them restored by any Thing; but 1. They will lose their Forces like elastic Bodies. They will pass into the insensible Parts; since the insensible Parts will strike, break, reflect, and give one another a Thousand different Directions in Proportion to their Texture, and the common Forces of the two Bodies. 2. Nothing will restore them their common Forces, since they have no Elasticity: Therefore, &c.

RULE V.

If B and C strike one another with unequal Forces.

They will lose their common Motion; it will become proper to the imperceptible Parts by the fourth Rule: But the stronger will divide its Excess of Force with the weaker in Proportion to the two Masses, since by this Excess it will strike the weaker, as if it found it at Rest.

Eud. I look upon the Rule, which we have been discoursing of, as a Principle of a Thousand and a Thousand divers Effects in Nature,

On the Percussion of soft Bodies. 157

Nature. Nevertheless it must be granted, *Aristus*, that among sensible Bodies there are none probably that are either perfectly hard, or entirely elastic, or absolutely soft; but they ought to follow the Rules just laid down, more or less, exactly in Proportion as they approach more or less to Bodies perfectly hard, elastic, or soft.

Let us at last see the Use of Motion and its Effects in the different Species of Bodies, which compose the Universe. But let us begin with forming some general Idea of the Universe itself, by considering the Sphere which Art presents to our Eyes.



CONVER-



CONVERSATION XIII.

Upon the Sphere.

Eud. **W**E have not, *Aristus*, (either you or I) Eyes piercing enough to penetrate so far as the Surface of the World; we don't see the external Figure of it: But if we judge of it by the common Persuasion, and by what is offered to our Senses, when the Weather is serene, and the Heaven sparkles with Stars, the World is round: It is a Sphere.

Arist. One may distinguish in the Sphere of the Heavens, as one does in an artificial celestial Sphere, different Parts, an Axis, two Poles, six large Circles; the Zenith, the Nadir, four Cardinal Points, the two Points of the Equinoxes, the two Points of the Solstices, four small Circles, and five Zones.

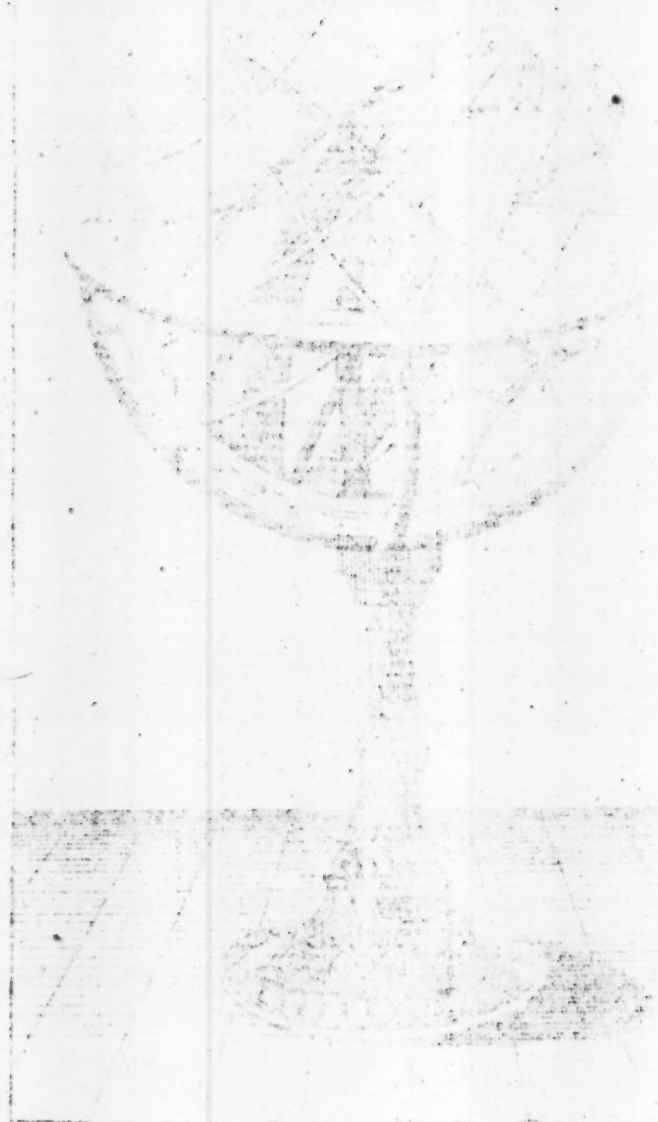
Eud. You seem to have, *Aristus*, a just Idea of the different Parts of the artificial celestial Sphere, *Fig. 14.*

Arist. 1. The Axis of the Sphere is the Line that passes thro' the Center of the Earth (*b*) esteemed as the Center of the Sphere, or the Diameter (*a b c*) upon which the Sphere turns.

2. The

fig. 14.





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2. The two Poles (*a, c*) of the Sphere, are the two Extremities of the Axis.

3. The six large Circles have for their Center, the Center of the Sphere. These Circles are, the Horizon, the Meridian, the Equator, the Zodiack, the Colure of the Equinoxes, and the Colure of the Solstices. Every Circle contains 360 Parts or Degrees. An Arc of 90 Degrees, comprehended betwixt two Lines, diverging and united in a Point, is the Measure of a right Angle: A less Arc, of an acute Angle; and a greater Arc, of an obtuse.

The Horizon (*d*) is a Circle which divides the Sphere into two halves of a Sphere, or into two Hemispheres, the one superior, in the middle of which we are, and which we see; the other inferior, and which we see not.

The Horizon has its two Poles, as well as the other Circles. The Poles of a Circle are the opposite Points, equally distant from all the Points of the Circle. The Poles of the Horizon are called Zenith and Nadir: The Zenith is over our Head; the Nadir is the Point diametrically opposite. Hence every one has his Horizon, Zenith and Nadir; and whenever he moves, he changes Horizon, Zenith, and Nadir.

Four Points of the Horizon are the four Cardinal Points, the East, West, South, and North. The East is that Point of the Horizon where the Sun rises. The West is that Point where the Sun sets. The South, with
respect

160 CONVERSATION XIII.

respect to us, is that Point where the Meridian cuts the Horizon on the Side of the Sun; and the North, the Point opposite.

The Meridian (*e*) is a Circle, which passes both thro' the two Poles of the Sphere, and thro' the Zenith and Nadir, cutting the Horizon at right Angles, or without inclining more to one Side than the other.

The Equator (*f*) is a Circle, which cuts the Meridian at right Angles, and which is equally distant in all its Points from the two Poles of the Sphere.

The Zodiack (*g*) is a Circle, which cuts the Equator, making with it acute Angles of 23 Degrees and a half, or which is 23 Degrees and a half distant toward the two Poles. It has 16 Degrees of Breadth, or thereabouts. Its Breadth is divided into two equal Parts by a circular Line (*k*) which the Sun runs, or seems to run over in a Year; and this is the Ecliptick. The Zodiack has 12 Parts, every one of which has 30 Degrees, and contains a Constellation or Sign; that is, a certain Number, a Collection of Stars. They call those Signs, going from the West toward the East, *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, and *Pisces*. The two Points where the Ecliptick cuts the Equator, or Equinoctial Line, are the Points of the Equinoxes. When the Sun is in those Points, the Length of the Light and Darkness is equal. The two Points, where the E-

I

ecliptick

cliptick is farthest distant from the Equator toward the North and South, are the Points of the Solstices, where the Sun begins to return toward the Equator.

The Colure of the Equinoxes (*b*) is a Circle, which passes both thro' the Poles of the Sphere, and also thro' the Points or Sections of the Equinoxes. The Colure of the Solstices (*i*) is a Circle, which cuts the other Colure at right Angles, passing thro' the two Points of the Solstices.

4. The small Circles of the Sphere are those which have not for their Center the Center of the Sphere, neither do they divide it into equal Parts: There are four of them, two Tropical, and two Polar, all of them parallel to the Equator. The two Tropics (*l, m*) are 23 Degrees and an half distant from the Equator, the one towards the South, and the other towards the North. This touches the Zodiac in *Cancer*, and is the Tropic of *Cancer*, and nearest to us; the other in *Capricorn*, is the Tropic of *Capricorn*, and farthest from us: They are called Tropics, because the Sun, whenever he touches the one, begins again to draw nearer to the other.

5. The Polar (*n, o*) are Circles 43 Degrees distant from the Tropics, and 23 and a half from the Poles. The Poles of the Zodiac are in the Polar Circles.

6. The Zones are the Spaces contained betwixt the Tropics and Polars. There are five

162 CONVERSATION XIII.

Zones ; the torrid Zone, two temperate Zones, and two frigid. The torrid Zone is betwixt the two Tropics ; the two temperate Zones are betwixt the Tropics and the Polars ; and the two frigid Zones are betwixt the Polar and the Poles.

Thus, I think, you have the artificial Sphere described in few Words : But pray, *Eudoxus*, make me see with the Eye, if possible, where, in the Heavens, Astronomers place those Circles, Points, and Zones.

Eud. The Season and Weather are favourable enough. It is the Equinox, the Heaven is serene, and the Stars are brilliant. Let us go up upon this Platform, where sometimes I observe the Stars. This large Circle, whose Circumference terminates the Sight on all Sides, is the sensible Horizon, which only differs from the true one by a Semi-diameter of the Earth, supposing the Center of the Earth to be the Center of the World. The Point, where we saw the Sun this Morning rise toward the left Hand, above the Horizon, is the East. The Point, where this Evening we saw the Sun go down toward the right, below the Horizon, is the West. The horizontal Arc which we saw on the Side of the Sun, from the rising to the setting, let it be divided into two equal Parts : The middle Point is the South. Let us turn our Eyes toward the Point directly opposite, that is the North. Lift up your Eyes, and you may see toward the North seven Stars very brilliant,

four of which are disposed almost in the Form of an Oblong Square, and the other three in Form of the Arc of a Circle, and of a Tail. That is the Constellation which they call *Ursa Major*, or *Charles's Wain*. You may see at some Distance seven other Stars, which make much the same Figure, but shine with less Lustre: This is the *Lesser Bear*. The last Star of the Tail is the *Polar Star*; it is near the Arctic, or North Pole. The opposite Pole of the Heaven is the *Antarctic*, South, or Meridional Pole.

The first is elevated about 49 Degrees in regard of *Paris*, and the other as much depress'd below the Horizon.

Arist. Virgil inform'd me of that a long time ago.

*Hic Vertex nobis semper sublimis; at illum
Sub pedibus Styx atra videt, manesque pro-
fundi *.*

Eud. The Point of the Horizon where we are, is the Center of the Circle: The Point of the Heaven, the most elevated directly over us, is our Zenith, the Point directly opposite is the Nadir.

The Circle which passes through these two Points, and thro' the two Poles, is our Meridian: When the Sun is in it, it is Noon with respect to us, or the half of the Day. Hence, when one goes toward the East, or toward the West, one changes both Meridian and Zenith.

* Book I. of *Georg.*

164 CONVERSATION XIII.

The Circle which cuts our Meridian at right Angles, 90 Degrees distant from the Pole which you see, the Circle distant from the Pole 90 Degrees in all its Points; the Circle, in a Word, which the Sun describes by his daily Motion at present, the 21st of *March*, the Day of the Equinox, is the Equator, or Equinoctial Line.

The Moon cuts the Equator, making acute Angles with it on both Sides; and the Circle which it describes every Month, going obliquely, but very sensibly, from the West toward the East, is in the Zodiac. The Planets, *Mercury*, *Venus*, *Mars*, *Jupiter*, *Saturn*, those Species of Stars which we see shine without any sparkling, while others send forth Rays on all Sides, are also in the Zodiac. The Planets make their Revolutions in the Zodiac, and according to *Tycho*, a famous Astronomer in this Order, *Fig. 15.* the Earth in the Center of the World, round about the Earth the Moon, the Sun carrying along with it *Mercury* and *Venus*, and round about it *Mars*, *Jupiter* and *Saturn*. The Planets make their Revolutions in the Zodiac round about the Sun, according to *Copernicus*, another famous Astronomer, and in this Order, *Fig. 16.* the Sun in the Center of the World, *Mercury*, *Venus*; the Earth with the Moon, *Mars*, *Jupiter*, and *Saturn*. We shall see one Day what we ought to think of the Situation of the Sun and Earth. However that be, the Moon has its different Phases in the Zodiac. It is there new, or in Conjunction, when it is betwixt the Sun and the Earth; Full,
or

fig. 15.

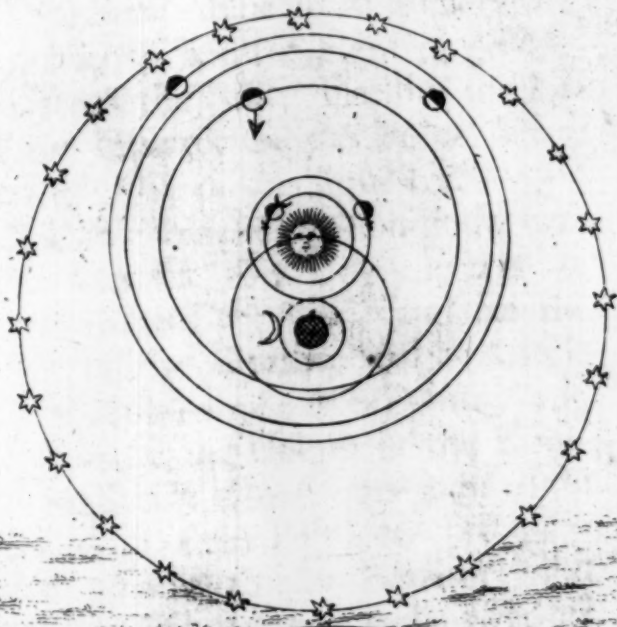
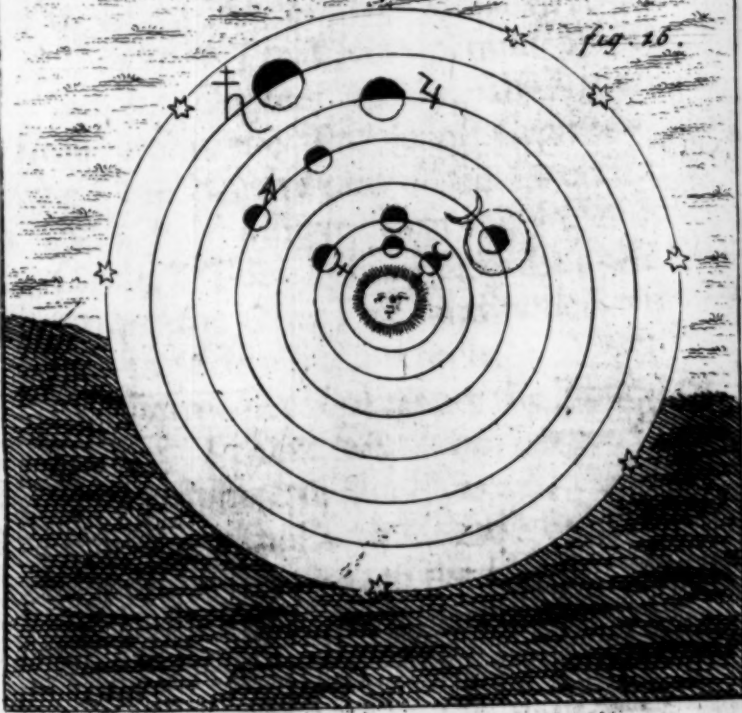


fig. 16.



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or in Opposition, when it is 180 Degrees distant from the Sun, or when the Earth is betwixt it and the Sun. It is in its Quadratures or Quarters, when it is three Signs or 90 Degrees distant from the Sun. Finally, the Ecliptick cuts the Equator in the Point where the Sun is on the Day of the Equinox.

Call to Mind the Point of the Horizon where you saw the Sun set this Day the 21st of *March*. Look toward the East, and see the opposite Point of the Horizon. The Circle which passes through those two Points, and through the Poles, is the Colure of the Equinoxes; and the Circle which cuts it at right Angles is the Colure of the Solstices.

The Circle parallel to the Equator, but nearer to us by 23 Degrees and an half, is the Tropic of *Cancer*. The Circle parallel to the Equator, but 23 Degrees and a half farther distant from us, is the Tropic of *Capricorn*. Look toward the North Pole. The Circle 23 Degrees and a half distant from the Pole, is the polar Circle. The Circle 23 Degrees and a half distant from the other Pole, and which we do not see, is the other polar Circle.

Lastly, the intermediate Spaces are the Zones.

Arist, I have, I think, *Eudoxus*, a pretty clear Idea of the Sphere of the Heavens.

Eud. They esteem the Earth itself as a Sphere, as a Globe. They give to it as to the Heaven, its Poles, its Circles, its Points, its Zones, so that the Poles, Circles, Points and Zones of the Earth, answer to the Poles, Circles, Points and Zones

166 CONVERSATION XIII.

of the Heaven. This is what one may see with a Glance of the Eye in a celestial Sphere bored through, which contains in it a terrestrial Globe. The Earth has its Parallels. These are Circles parallel to the Equator, Tropics, and Polars.

The Spaces contained betwixt the Parallels and Meridians, are Climates. The Meridians are moveable, except the first which the *French* fix in the Island of *Fer*, the most westwardly of the *Canary* Islands. Lastly, the Circles of the Sphere have their Uses.

Arist. And those Uses are sufficiently evident, after what we have said.

1. One sees the East and West in the Points of the Horizon, where the Sun rises and sets; and the North and South in the Points of the Horizon that are cut by the Meridian. It is in the Horizon, that we see Night succeed Day, and Day succeed Night. The Horizon separates the upper Hemisphere from the inferior, the visible from the invisible in Regard to us.

2. The Meridian divides the World into two equal Parts, the one East, the other West. Hence, the Sun being in the Meridian, it is Mid-day above the Horizon, and Mid-night below the Horizon. The Meridian serves farther to determine the Elevation of the Pole; since the Arc of the Meridian contained between the Pole and the Horizon, expresses the Height of the Pole. What is the Longitude of any Part of the Earth? It is its Distance
from

from the first Meridian, reckoning from West to East. The Latitude is the Distance from the Equator. There is a North and South Latitude. Both the one and the other is determined by the Arc of the Meridian, or by the Degrees contained betwixt the Equator and any Place North or South.

3. The Equator divides the World into two equal Parts, the one South, and the other North. In this Circle the Equinoxes happen, about the 21st of *March*, and 23^d of *September*. When the Sun is in this Circle, it is as long above the Horizon, as below it. Hence the Length of the Day and Night is equal. The Equator is moreover the Measure of Time, since the Sun runs over the 360 Degrees of this Circle in 24 Hours. What is the Declension of the Sun and Stars? Their Distance from the Equator, and the Degrees of the Meridian contained betwixt the Equator and Stars, are the Measure of their Declension.

4. The Sun, Moon, and Planets make their Revolutions in the Zodiack; and the Motion of the Sun, according as he approaches or removes from the divers Climates, so that his Rays are more or less oblique, make the different Seasons; the first Equinox the 21st of *March*, and the Spring, by passing in the Space of three Months from the Equator to the Tropic of *Cancer*, where the Summer Solstice happens the 21st of *June*, the Summer returning through other Signs in three Months from *Can-*

168 CONVERSATION XIII.

cer to the opposite Point of the Equator, where the second Equinox happens the 23^d of September; the Autumn, going in three Months from the Equator to the Tropick of *Capricorn*, when the Winter's Solstice happens the 21st of December; and the Winter, returning from *Capricorn* in the Space of three Months, and through three other Signs, to the Equator.

5. One sees in the Colures, though their Use does not seem very necessary, the Points of the Equinoxes and Solstices.

Finally the small Circles, the Tropicks and Polars divide the Earth and the World into five Zones.

Eud. It is worth while to observe farther the Position of the Sphere; that is the Situation of the Horizon in Relation to the Equator. Hence, there are three different Positions of the Sphere; one right, the other oblique, and the third parallel. It is right, when the Horizon cuts the Equator at right Angles. It is oblique, when the Horizon cuts the Equator at unequal Angles: It is parallel, if the Horizon is parallel to the Equator, or confounded with it. Those who inhabit under the equinoctial Line have a right Sphere; we have an oblique; and if there are Men under the Poles, they have a parallel one.

Will you tell me, *Aristus*, what Stars ascend above the Horizon, and descend below it every Day in a right Sphere, or with Respect to the Inhabitants of the equinoctial Line?

Arist.

Arist. The Stars cannot all turn round about the Axis and Poles of the World every Day without ascending all, or almost all, above the Horizon, and descending below the Horizon every Day in a right Sphere, since in a right Sphere the Horizon passes through the Poles. Now all the Stars turn sensibly about the Axis and Poles of the World every Day: Therefore all, or almost all the Stars ascend above, and descend below the Horizon, every Day in a right Sphere.

Eud. But in the oblique Sphere, at *Paris*, for Example. —

Arist. Some Stars are there always above the Horizon, and others are never there. Let us suppose that the Height of the Pole is 49 Degrees; all the Stars contained in this Space, never descend below the Horizon, the Horizon being 49 Degrees below the Pole. All those which are not above 49 Degrees distant from the opposite Pole, never ascend above the Horizon; the Horizon being 49 Degrees above this Pole.

Eud. But lastly in a parallel Sphere, under the Pole. —

Arist. One ought always to see there the same half of the Heaven: For one ought always to see there the half of the Heaven contained between the Pole and the Equator, since the Equator and Horizon is the same Thing. Now this half of the Heaven is always the same;
it

170 CONVERSATION XIII.

it is moved parallel to the Equator or the Horizon, without descending: Therefore, &c.

Eud. By the same Reason, in the parallel Sphere, or under the Poles, there is a Day of six Months, and a Night likewise of six Months, or thereabouts. For the Day lasts as long as the Sun is above the Horizon; and the Night as long as the Sun is below it; but in the parallel Sphere, the Sun is six Months above the Horizon, and six Months under it; since it is six Months on this Side, and six on the other Side of the Equator, running through the Ecliptic in a Year, and since the Horizon is the Equator itself.

But, *Aristus*, what Method would you take, to know what Hour it is in any Countrey?

Arist. In one Hour the Sun makes 15 Degrees of his Circle by his daily Motion over the Equator, or parallel to the Equator; from East to West. For he runs through the Circle in 24 Hours, and 24 Times 15 are 360. For which Cause, if it is Noon in the Meridian of *Paris*, it is an Hour after Noon in the Meridian 15 Degrees farther Eastward: There must have passed an Hour for the Sun's coming from that Meridian, to the Meridian of *Paris*. It is only eleven of the Clock in the Place 15 Degrees more Westward; there must be an Hour for the Sun's passing from the Meridian of *Paris*, into the Meridian of that Place. Two Hours after it is Noon in a Place 30 Degrees more Eastward, &c. 10 of the Clock in the

the Morning in a Place 30 Degrees more Westward. This being granted, all I have to do is to look upon a terrestrial Globe for the Differences of Longitude, and knowing what Hour it is at *Paris*, I have the Difference of the Hours. I find, for Example, that when it is Noon in the Meridian of *Paris*, an Hour after it is Noon at *Vienna* in *Austria*, past three at *Hispahan*, seven in the Evening or thereabouts at *Pekin*, and Midnight in *New Zealand*: Since *Vienna* is a Place 15 Degrees more Westward, *Hispahan* 50, *Pekin* 110, and *New Zealand* 180; and because 50 contains 15 more than three Times, 110 more than seven Times, and 180 more than 12 Times.

Eud. With the same Ease you will find Places that are Antipodes to one another.

Arist. I need only look in any Meridian for two Points 180 Degrees distant from one another. Those two Points are Places that are Antipodes; for in a Word, the antipodal Parts of a terrestrial Globe, are the two Points diametrically opposite. Now two Points of a Meridian, 180 Degrees distant from one another, are the Points diametrically opposite; since they are the two Extremities of the Diameter, which divides a Circle of 360 Degrees.

Eud. These easie Perceptions will facilitate such as more difficult. I have made a Discourse

172 CONVERSATION XIV.

course upon the Earth, and the Minerals which it contains.

Arist. And this Evening I will return to your Closet, and will not leave you till you have imparted it to me.



CONVERSATION XIV.

Upon the Earth and Minerals.

Eud. I Promised you, *Aristus*, the Discourse I have made upon the Earth and Minerals; here it is.

One may look upon the Earth as a pure Body without Mixture, or as a mix'd Body, whose Surface is the Habitation of Men and Animals.

The Earth, pure and without Mixture *, is a Body, whose Parts are ramose and very gross;
ramose,

* The Word *Earth* among the Naturalists denotes the terrequeous Globe; and in Agriculture, signifies that compound Matter which serves for the Production and Growth of Vegetables planted therein; but the Chemical *Earth* differs widely from them both, as being a *perfectly homogeneous, or simple Body, hard, friable, insoluble in Air or Water, fixed, and incapable of flowing in the Fire, but remaining immutable, and retaining its own Form and Quantity in them all.* We term it a Fossil, as being exceeding simple or inorganic, without any Distinction of Vessels or Juices;

Upon the Earth and Minerals 173

ramose, for whenever they are joined together, it is a Compound which has very much Consistence, and shuts out the Passage of Light; very gross, since Fire agitates and dissolves them with great Difficulty.

The Earth, considered as a mix'd Body, is a Body of a round Figure, or thereabouts, vaste, fertile, and containing different Beds of Clay, Chalk, Sand, and divers Minerals.

1. The Earth is physically round. Every considerable Portion of the Surface of the Earth cannot be an Arc of a Circle, without the Earth be of a round Figure. But every Portion of the Surface of the Earth is an Arc of a Circle. Go from South to North, or from North to South: You will see new Stars arise above the Horizon. If you advance 15 Degrees toward the East, the Sun rises an Hour sooner with Respect to you. Should you go 15 Degrees toward the West, the Sun rises an Hour later in Regard of you. When one

Juices; and proceeding originally from the common Matter of the terraqueous Globe; 'tis called simple, because all its Parts appear of the same Nature with the Whole: We define it hard, because it resists the Separation of its Parts; friable, because it may be broke into less Masses, and fixed in the Fire, because with whatever violent Degree of Heat it is every Way surrounded, it loses nothing of its Weight or Bulk, yet without running into Glass; but possibly the Focus of a large burning Concave, may cause some alteration therein; though it would lose considerably less than any other Body in Nature, even Gold itself; the most violent Fire being unable to break the Cohesion of its Parts, which is a very uncommon Property. 'Tis so simple, that though it enters into the Composition of all other Bodies, yet itself can never be resolved into any different Substance. *Vide Shaw's Chem.* 325.

leaves

174 CONVERSATION XIV.

leaves the Harbour of a Town, so as to sail toward any Place whatever; one loses the Sight of the Harbour, and then the Walls of the Town, and last of all the Top of the Towers. Let any one at that Instant go up upon the Scuttle of the Mast, and he will immediately see again the Top of the Towers, then the Walls of the Town, and lastly the Harbour. But these Objects disappear again, as they did the first Time. Whence comes it, if not from this, that every considerable Portion of the Surface of the Earth is an Arc, the Middle of which being, in some Sort, elevated in Regard of you, with-holds from your Eyes, when you are at one of the Extremities of the Arc, that which would not be concealed from you, if you were at the other Extremity? In a Word, when the Earth, placed betwixt the Moon and the Sun, causes an Eclipse of the Moon, as we shall mention hereafter, why is the Shadow formed like an Arch, which is spread over the Moon? Because the Surface of the Earth, which projects this Shadow in Form of an Arch, is an Arch itself. Therefore the Earth is a round Body.

The Earth, I say, is nearly of a round Figure. 'Tis evident that it is not geometrical-ly round, since one sees upon its Surface Mountains whose Summits are lost in the Clouds. But the Height of the highest Mountains is smaller in Regard of the Earth, than the Height of the small Inequalities on an Orange-peel,

peel, in Regard to the Orange itself. The Height of a Mountain a League high, is contained almost 3000 Times in the Diameter of the Earth; for the Diameter of the Earth is about 2860 Leagues; since the Diameter of a Sphere is near a third Part of its Circumference, being as seven to 22; and the Earth is a Sphere whose Circumference is 9000 Leagues, as we shall see by and by. The Height of the small Inequalities of an Orange, is it contained so many Times in the Diameter of the Orange? •

Another Reason, which proves that the Earth is not perfectly round, is, because according to the Trials of *M. Cassini*, for determining the largeness of the Earth, its Surface ought to have the Figure of an Ellipsis † prolonged toward the Poles ‡, and of which one Property is, that being divided into Degrees, every one of those Degrees augments in Proportion as they approach the Poles; so that the Circumference of a Meridian of the Earth, ought to exceed the Circumference of

† According to Sir *Isaac Newton* the Figure of the Earth is an oblate Spheroid, it being every where higher in the *Æquator*, than in the Poles, consequently its Poles must be depressed, and not prolonged. Astronomers have likewise observed the same of *Jupiter*, namely, that its Axis is shorter than its *Æquatorial Diameter*; for though this Planet be the greatest of all the Planets, it is moved the swiftest about its Axis, and therefore this Difference may be observed.

‡ *Hist. de l'Acad.* 1718. suite de l'année pag. 237, 238.

176 CONVERSATION XIV.

its Equator about 54 Leagues^r: But this Excess does not hinder but that the Earth may be physically round.

2. The Earth is a vaste Body. A round Body, whose Circumference is 9000 Leagues, is a vaste Body. The Earth is a round Body, whose Circumference is about 9000 Leagues. Every great Circle of the Earth has 360 Degrees; every Degree, according to *M. Piquart*, contains 25 Leagues of 2282 Fathoms, the Degrees of a Meridian, though unequal, contain almost so many, one with another, according to *M. Cassini* himself^u. In a Word, advance about 25 Leagues from South to North, the Pole appears to you elevated one Degree. Now 25 Leagues repeated 360 Times, are 9000 Leagues; multiply 360 by 25, the Product is 9000.

3. The Earth is a fertile Body, since it affords us Flowers in Spring, plentiful Harvests in Summer, and Fruits in Autumn.

4. The Earth contains different Beds. In the Brink of great Rivers, and in Hills cut perpendicularly, you may often see a Bed of Clay, then one of Sand, one of Chalk, one of Stones, of Gravel, &c. Father *Mersenne* reports, that in making a Well at *Amsterdam*, they drew out successively seven Foot of Clay, nine of Turf, ten of Potters-Clay, eight of Sand, four of Earth, ten of

^r Ibid.

^u Pag. 247.

Potters-Sand, two of Potters-Clay, four of white Sand, one of Turf, fourteen of Sand mixed with Potters-Clay, four of Potters-Clay mixed with Sand, twelve of pure Potters-Clay, and thirty one of Sand *.

Finally, the Earth contains in its Bosom divers Minerals, since they are drawn out of it. Therefore the Earth, considered as a mixed Body, is a Body round, or thereabouts, vast, fertile, and containing different Beds of divers Matters, divers Minerals.

They call Minerals the fat or lean Juices which are drawn out of the Earth, Metals and Stones.

I. Oil, Sulphur, Bitumen, Pitch, Amber, are of the first Sort of Juices. Common Salt, Mineral Salt, Vitriol, Allum, Nitre, Salt-Peter, Sal-Armoniac, &c. of the second.

Oil is a Body whose Parts are ramose †, flexible, and impregnated with much subtile Matter.

* Bayle, T. II. p. 279.

† By considering what has been said concerning Attraction and Repulsion, we shall be better enabled to account for the Generality of chymical Experiments, than by imagining them to consist of Particles hooked, pointed, blunted, &c. For Example, by Attraction we may easily understand why Quicksilver unites itself to Tin and Gold; and also why Water and Oil stick to Wood and clean Glass. We have Instances of Repulsion between Water and Oil, and generally between Water and all unctuous Bodies; between Mercury and Iron, as also between the Particles of any Dust.

The Particles of any Salts attract one another with a very great Force, as appears by several Experiments: The following will be sufficient to prove, that that Attraction exerts itself at a very small Distance, and the repellent Force at a greater.

178 CONVERSATION XIV.

Matter. Hence Oil is diffused, clammy, fluid and easily inflamed.

Sulphur is an oily Body, whose small Branches are shorter, more compact, and surrounded with subtile Matter. Hence Sulphur is neither soft, nor fluid, as pure Oil, but is very inflammable.

Bitumen is a Compound of Oil, Sulphur, terrestrial and gross Parts; accordingly Bitumen is hardened and inflammable like Sulphur, and oftentimes Water itself only renders it more hot; because the grosser Parts of the Bitumen being inflamed, repel the Water, and the Water which resists hinders the Parts of the Bitumen from dissipating presently.

Pitch and Amber are Species of Bitumen. Pitch is a Bitumen which is immediately drawn from the Earth; and Amber a Bitumen which the Waves of the Sea throw upon the Coasts, where it is hardened by Cold and Heat.

Common Salt is a Collection of long, strait, stiff and sharp Parts. *In short, it pricks, fur-

Dissolve Salt in Water, and when that Water is reduced into Vapour, the small saline Particles will unite together and form greater Lumps; which proves the Attraction.

These Particles are all equal, and of the same Figure: Whence it follows, that the least Parts of which they are formed, had every where the same Situation in Respect to each other; that is, were every where diffused in the Water at equal Distances; which cannot be, unless they all repel one another with equal Forces. Confer Notes on CONVERS. IX. *Vide Newt. Opt. Que. 31.*

nishes

nishes effectual Menstruums, and preserves Meats by penetrating them, contracting their Parts, and by that Means hindering the Action of the Air and subtile Matter from separating and corrupting them. There are Mountains in *Poland* all full of Salt. They find Mines of it in *Castile*. In the Dukedom of *Cardonne* in *Spain*, there is a Mountain of Salt of all Colours^y. Hence salt Waters.

But what Method do they use to draw Salt from the Sea? In Summer they make Choice of low Places, Pits. In those Salt-Pits they raise Banks towards the Sea. When it is high Tide, they open Sluices to receive the Salt-Water into some Reservoirs. After that they shut the Sluices, and let the Water evaporate, till there remain but so much as is necessary for keeping the Salt in a certain Agitation. When the Water is prepared after this Manner, they make it run into small Channels, much like the Walks of a Parterre, and whose Ground is Potter's Earth, which imbibes no Water^z.

Mineral Salt is a fossile Salt, transparent, and harder than Sea Salt.

Vitriol is a Mixture of Sulphur, an acid or sharp and pointed Salt, Phlegm, Earth, Iron, and Copper: For 1. Sometimes a sulphureous Odour is exhaled from it^a. 2. If you put Vi-

^y Bib. univ. & hist. 1691.

^z Regis T. 2. p. 205.

^a Mem. de l'Acad. 1713. p. 174.

180 CONVERSATION XIV.

triol into a crucible, and thrust it into the Fire, you have a sharp and pointed Salt drenched in Phlegm, and this is what they call Spirit of Vitriol. 3. Spirit of Vitriol being poured upon Iron, whose Sulphur it corrodes, is reincorporated with Vitriol. 4. Chymists draw from it Earth and ferruginous Particles. 5. Iron being put into a Solution of Vitriol, is charged and striated with Particles of Copper. Father *Kircher* speaks of vitrioline Waters, in which Plates of Iron seem to be changed into Copper, the Parts of the Copper taking the Place of those of Iron, without any real Transmutation*. Rub a Plate of Steel with Particles of blue Vitriol wetted: The Particles of Copper are fixed in the Pores of the Surface of the Steel, and you would say that the Steel is changed all of a sudden into Copper.

Allum differs little from Vitriol, except that the Spirit of Allum is sharper; whence it comes to pass, that the Acid of Allum is less agreeable.

Allum, Vitriol and Sea Salt, however pure they be already, afford a saline and oily Liquor, and deposite a very fine Earth^b.

Nitre is a different Acid, contained in a volatile Salt; and Salt-Peter is the same Acid, strongly engaged in a fixed Salt, according to the chymical Observation of *M. Lemery*^c. Ni-

* Kirker de M. sub, p. 321.
p. 32.

^c Ibid.

^b Mem. de l'Acad. 1713.

tre becomes Salt-Peter by the Mixture of a foreign fixed Salt ^d. The fixed Salt of Ashes cast upon the Dung of Animals afford Salt-Peter. Salt-Peter is a Salt whose Surface is more rugged than common Salt. Accordingly, 1. Salt-Peter is melted more easily, because the Inequality of its Parts receives the Action of the Water more easily. 2. The Salt-Peter is more light, because having a more unequal Surface, it is more porous. Salt-Peter fuses and gives a Force to the Flame, because it has solid Parts which are divided successively, and bound with Violence every Way. They gather it up upon the Sides of the Walls of Caves, like a sort of salt Flower. The best comes from the *East-Indies*. Throughout all *Europe* they draw much of it from old Plaister, from the Earth of Church-yards, from Pigeon-Houses, Stables ^e, and from Plants; and as it is drawn from Plants which sometimes one sees fuse in Fire, and from the Dung of Animals where it seems to be brought to Perfection, it may pass for a vegetable and animal Salt, as well as for a mineral Salt. In short, they find Mines of Sulphur, common Salt, mineral Salt, Vitriol and Allum; But there are none of Salt-Peter to be found ^f.

Sal Armoniac is a volatile Salt, urinous, and penetrated by an Acid, which cuts, divides

^d Ibid. 1717. p. 127.
^f Ibid.

^e Hist. de l'Acad. 1717. p. 29.

182 CONVERSATION XIV.

and corrodes. Put one Part of common Salt upon five of Urine; add half the Quantity of Soot: From this Mixture is sublimated a rarified Substance, white like Meal, lightly sticking together, and friable; and this is artificial Sal-Armoniac &c. Earths naturally loaded with common Salt, impregnated with the Urine of several Animals, and exposed to the Heat of the Sun, seem capable of furnishing a natural Sal-Armoniac.

As for Salt of Tartar, it is an acid Salt drawn from Tartar; and the Tartar is the Lees of Wine sticking to the internal Surface of Casks.

But finally, what is the most probable Origin of those terrestrial, oily or saltish Juices?

1. It is certain that the Earth is penetrated by a fine Matter agitated without Intermiſſion: For there happen incessantly Changes in the Bosom of the Earth; Exhalations issue out of it in the deepest Mines; the Mines of Stones and Metals being exhausted, are filled again with Stones and Metals. These Changes do not happen without the Transportation and Agitation of the Parts. Now, from what does this Transportation and Agitation immediately proceed, if not from the subtile Matter, constantly agitated, and what penetrates the Earth?

& Ibid. 1716. p. 29.

2. The Parts of the Earth being solid and irregular, there must be between them an infinite Number of Interstices of different Figures.

3. An Infinity of Particles of Matter driven into those Interstices, as into so many Moulds, by the Action of the subtile Matter, ought therein to take different Figures. Those Particles coming in the End to encounter and grapple with one another, compose divers Corpuscles, long, short, hard, flexible, smooth, rugged, blunt, sharp, or pointed. Such probably is the Original of terrestrial Juices, Oils, Sulphurs, and Salts; and from the Mixture of those Juices proceed Metals and Stones.

2. They call Metals Bodies that are solid, hard, capable of melting, and malleable; a Quality which distinguishes them from Stones. Divers Mixtures of long and ramose Parts, of Oil, Sulphur, Salt and Earth, make divers Metals; Tin, Iron, Copper, Silver, Lead and Gold. For 1. With Sulphur, Vitriol and Earth, they make a Species of artificial Iron. 2. From most Metals they draw Parts of Oil, Sulphur, Salt or Earth. 3. Why do Metals melt, and lengthen by a Wiredrawing Iron, or at least under the Hammer? Because their long and ramose Parts run upon one another without quitting their Hold. Different Exhalations, oily, sulphurous, saltish, and earthy, being raised up by the Action of the subtile Matter, and mixed toward the Surface of the Earth,

184 CONVERSATION XIV.

make therein metalline Veins, from which they draw divers Metals.

The Gravity of Metals is very unequal. Tin affords 532 Pounds in one cubical Foot, Iron 576, Copper 648, Silver 744, Lead 828, and Gold 1368.

Tin contains sulphurous Parts, since it is inflamed with Salt-Peter; ramose and flexible, for it melts, and easily yields to the Hammer; considerably distant from each other; in a Word, it weighs less than other Metals.

Iron is a Compound of Sulphur, vitrioline Salt, and Earth. Did not *M. Geofroy* make Iron by a Mixture of these three Principles? At least he made a Powder, black, heavy, and cleaving to the Loadstone; a specifical Mark of Iron^h. Its Parts are stiff and gross: Accordingly it yields with Difficulty, whether to the Fire, or to the Hammer. But they are considerably distant from one another, for it is lighter than the most Part of other Metals; and of the Number of those which are most easily dissolved by *Aqua Fortis*. There is hardly any Countrey in the World, especially towards the Poles, where Nature does not produce Iron. They draw it from the *Argilla*ⁱ, and from an infinite Number of Fossils. How many mineral Fountains are impregnated with it? They find it in the Ashes of Plants. *M.*

^h Hist. de l'Acad. 1704. p. 39.
Journ. des Sçavans, 1719. p. 378.

ⁱ Zanibelli. De ferro.

Geofroy

Upon the Earth and Minerals. 185

Geofroy examining with a Knife, touched by a Loadstone, the Ashes of a Vine Branch, of Herbs, and of Wood, exactly reduced to Lye-Ashes, always found Parcels of Iron, and he esteemed it as a Thing impossible to make Ashes without making Iron also ^k. Did not the Royal Society of *London* see Grains of Iron drawn from an humane Stone, calcined by Dr. *Lister*^l? Probably those Particles pass from the Vegetables into the Animals themselves.

Steel is only refined Iron. According to the Experiments of *M. Reaumur*^m, the most proper Composition for converting into the hardest, finest, and best Steel, Irons fittest for becoming Steel, consists in two Parts of Soot, one Part of beaten Coal, one Part of Ashes, and about three Fourths of a Part of Sea Salt, or something less. If you use sixteen Pounds of Soot, you must use eight of Coal, eight of Ashes, and six or five only of Sea Salt.

There must be a less active Composition for other Irons; two Parts of Ashes, one of Soot, one of Coal, three Fourths of a Part of Sea Salt, or thereabout.

This last Composition may be used with Success upon the Iron of the first Species; but the Operation thereof is slower and longer. The Soot, Coal, Ashes, and Salt require some Preparation. They make the Soot pass thro'

^k Hist. de l'Acad. 1705, p. 65.

^l Journ. des Sçav. 1719.

p. 378.

^m L'Art de convertir le Fer en Acier.

186 CONVERSATION XIV.

a gross Searce, or through a sort of Sieve. The finer it is, it will be so much the more effectual. The Coal is pounded; after that it is made to pass through a Searce moderately fine. The Ashes are good, provided they are of new Wood: They make them also pass, like the Coal, through a Sieve. As for the Sea Salt, it is reduced into a very fine Powder.

The Mixture of Soot, Coal, Ashes and Salt, is well made, when the Matter appears to be of the same Colour, in whatever Part one looks on it.

Lastly, they surround Bars of Iron with this Mixture; plaister the Whole over with Potter's Earth, and put it into a Stove over a violent Fire. In the Violence of the Agitation, the Particles of the Mixture, the Salts penetrate the Iron, comminute the Parts of it, drive out the earthy Matter which is not sufficiently wrought by Nature, fill up its Interstices, and bind its Parts together. Hence proceed the Fineness, the Flexibility, and the Hardness of the Metal; and this is Steel. Cy-meters have been made of Steel, so fine and hard, that they cut Bars of Iron without being blunted.

Iron melted, but quickly cooled again, is changed into hard and brittle Steel; hard, because the Particles are closely united; brittle, because the small Globules of the Steel only touch one another by spherical Surfaces.

M. Zani-

M. Zanichelli thinks that Iron contains a little Mercury. Present, says he, a Piece of polished Iron to Mercury, at the Distance of two Fingers Breadth, the Mercury flies to the Iron, and covers its Surface ⁿ.

Copper is compounded of more compact Parts than those of Iron, and of a Salt sharp and fixed; for which Reason Copper is more weighty than Iron; it is melted with greater Difficulty, and its Salt is proper for corroding of Flesh.

Silver has its Parts more compact and less porous than Copper; for which Reason it is heavier.

Lead is a Tissue of Parts more equal, more flexible, less ramose, and less separated; accordingly Lead is divided, bent and melted quicker, and is more ponderous.

Gold differs from Silver and Lead, in that it results from Parts which are at the same Time more gross, more ramose, more united, and less porous. Hence Gold is heated and melted with Difficulty; it is the heaviest of Metals, and may be drawn out almost to an infinite Length.

There are Minerals, which are not properly Metals, not being malleable; but which are notwithstanding Metalline, by Reason of the Parts which they contain; Antimony, for Example, in the Analysis which is made of it,

ⁿ Journ. des Sçav. 1719. p. 376.

appears

188. CONVERSATION XIV.

appears to be but a metalline Substance, mixed with a good deal of very volatile Sulphur, and a kind of acid Salt; whence Antimony causes vomiting. Quicksilver, which also contains something metalline, is a Body compounded of round, polished and slippery Parts, whose Pores allow a Passage only to the subtile Matter: For which Reason Quicksilver is fluid, and its Drops are formed round, because the Air which cannot penetrate them, by Reason of the Smallness of their Pores, thrusts them towards a common Center, until they equally resist it on all Sides under a spherical Surface. Lastly, native Cinnabar is a Mixture of Quicksilver and Sulphur; in a Word, Art produces one very like it from Sulphur and Quicksilver.

It is of some Importance to know by what Marks one may discern the Places where Nature conceals her Treasures. Oftentimes she seems to lay Snares for the Curiosity and Covetousness of Men, who being deceived by fine Appearances, open the Bosom of the Earth without Success. We have seen it opened near *Paris* with very considerable, but very useless Expences. But those Places of the Earth that appear burnt, protuberant and mixed with white Rocks like Sorts of Crystals, rarely deceive. These are Signs almost infallible of an abundance of Mines. Copper is discovered sometimes by the Verdigrease which it throws out from the Earth.

• Mem. de Trevoux. Sept. 1704. p. 1621.

Upon the Earth and Minerals 189

3. Stones do not differ from Metals, but in having their Parts less ramose, less interwoven, and consequently less proper for being melted, or extended under the Hammer. At least it is certain that there are Stones formed of Sulphur and Earth, since there are Flints which being rubbed against one another, send forth a sulphurous Smell. They distinguish two Sorts of Stones, common Stones and precious Stones.

There are some Stones formed of Chalk, and others of a fluid Matter, or of a soft Paste which dries and hardens. 1. There are some formed of Chalk, whose Parts are probably linked together by certain Sulphurs; for Stones are found in Quarries, where some Years before one found only Chalk, and the Stones are different according to the Diversity of Chalks. 2. There are some formed of a fluid Matter, or of a soft Paste. Stones cannot contain foreign Bodies within them, unless they entered when they were a fluid Matter, or at least a soft Paste. But there are continually found in some Stones, Leaves, Plants, Insects, Bones of terrestrial Animals, and of Men, yea whole Skeletons ^p, Fishes and Shells. Therefore, &c.

The Shells which are found in the Generality of Quarries, seem to prove that the Surface of the terrestrial Globe has been Mud and Mire drenched with the Water of the Sea, at least to a certain Depth. Therefore the Wa-

^p Hist. de l'Acad. 1716. p. 15. 1706. p. 10.

190 CONVERSATION XIV.

ter of the Sea has covered the whole Earth; and thence probably it is that the Shelves or Beds of Stones, which are found in the Plains, are ordinarily horizontal, and parallel amongst themselves.

When the Petrification of the same Mass has not been continued, but that one Part of it was done in a certain Time, and another Part in another Time, the Stone appears disposed in Form of Beds, like the Trunk of a Tree whose Accretion is interrupted in Winter.

The Variety of Stones proceeds from the Diversity of Mixtures. For Example, if some Oil happen to unite the Grains of Sand, it is brown Free-Stone. If the Parts of Salt and Oil, whose irregular Texture would make Sand, are united in such Manner that a Mass results from them whose Pores are direct, and leave a free Passage every Way for the Light, it is Crystal. In a Word, Crystal may be calcined like Free-stone. Are the Parts fit for composing Crystal more straitly united? It is Diamond. Some Parts of Metal in Compositions, which without this Mixture would make Diamonds, render the Compositions less hard, and make Colours to appear in them; and these are Agates, Emeralds, Topazes, Rubies and Sapphires.

There are Stones formed even of Wood itself. Wood is petrified, when Particles of

^a Jour. des Scav. 3. Feb. 1693.

Sand,

Upon the Earth and Minerals. 191

Sand, Chalk, Stones or Salt, insinuate themselves and sink into the Pores of the Wood, and are there fastened to one another. And if those small Parts are fastened by certain Mixtures of Sulphur, there is Metal formed in the Wood itself. They have found in petrified Wood a Vein of Metal, red and very fine. But a much more astonishing Petrification is that which Father *Kirker* mentions of a whole Village in *Africa* turned into Stone, with all that was in it, even to the Inhabitants themselves^r. For such an Event the Earth of that Countrey must needs have emitted a strange Quantity of Salt, to be capable of penetrating divers Bodies and there fixing themselves. The Fact might have appeared more marvellous, had it been less so. And if it were not too surprizing not to be suspected, there would be no greater Difficulty in believing what *Acosta* says of a Company of *Spanish* Cavaliers turned into Stones.

However that be, the Sea has its Stones. The *Galets* are Flints ordinarily round, and always polished, which the Sea throws upon the Coasts. Whence proceeds their round Figure, and their Smoothness? From their having been a long Time agitated by the Waves and worn against one another.

One would scarcely believe that Worms gnaw Stones. Nevertheless a Virtuoso, who found

^r Mund. Subt. T. II. L. VIII. Sec. 2. p. 50.

192 CONVERSATION XIV.

Worms in a gnawed Stone, shut them up in a Box with some Pieces of the Stone; and eight Days after he found the Pieces sensibly gnawed.

Those small Insects eat solid Bodies so much the more easily, as having a sort of Needles, very hard and sharp, they insert them more easily into the Interstices of Stones.

Will you subjoin nothing to this Discourse, *Aristus*?

Arist. I thought as you proceeded I saw the Hand of Nature forming precious Stones. But *M. Geofroy's* System^s upon the Origin of Stones has appeared to me very simple; here it is, I think, in few Words. Earth without Mixture is the only necessary Ground for Petrifications. There are two Sorts of primitive Parts in the Earth; the one which are very fine *Laminae*, and almost equal among themselves, and the other which have all Sorts of irregular Figures. The first being united in a sufficient Quantity make a homogeneous Body, very hard by Reason of the immediate Contact of the Parts, and transparent because of their regular Disposition, which leaves free Passages every Way for the Light; and this is Crystal. The other, less susceptible of immediate Contact, and a regular Disposition, only form opaque and less hard Collections. Crystals are only formed of the first; others are formed both of the first and second; the first are a stony cry-

^s Hist. de l'Acad. 1716. p. 8.

stalline Juice; Water, as one may observe from some stony Fountains, which incrust with Stone the Pipes through which they flow, is a proper Vehicle for carrying this Juice; this Juice is more weighty and fixed than Water, and is never evaporated with it.

This being granted, after what Manner is natural Crystal formed? Much after the same Manner as saline Crystals in Chymistry. A Water charged with Salt is evaporated slowly in a cool Place; the Salts which were too much separated, approach one another in the Evaporation; the Slowness of the Evaporation affords them, in their approaching one another slowly, Leisure for assuming, without Confusion, such an Arrangement as is fit; the Cold which diminishes the Agitation of the Water slowly, contributes to the two Effects; hence chymical Crystals. Water charged with crystalline Juice, fallen through the Clefts of a Rock to the Bottom, has permitted the Particles of the crystalline Juice to approach one another in the slow Evaporation; and this is Rock-crystal.

Crystal is not formed universally alike, because the crystalline Juice is unequally diffused. If Water charged with this Juice, passing thro' a Portion of Earth, bind the Parts of it together, and be evaporated, the Compound hardens into common Stone. The Stone approaches more or less to Crystal, according to the Quantity of crystalline Juice; and it is of a

194 CONVERSATION XIV.

finer Grain, according as the *Moleculæ* of Earth are more homogeneous and smaller; hence Marble. Finally, divers Mixtures of crystalline Juice and gross Parts make different Stones, Flints, Agates, &c.

Eud. The Hypothesis is ingenious, and I love to see you form Marble, Crystals, Agates, and precious Stones, after *M. Geoffroy*, in so simple a Manner. But there is no Stone that strikes me so much as the Loadstone.

Arist. You will teach me the Original of the Magnetic Virtue. I will endeavour to explain the Effects of it, after you have discoursed of the vulnerary Stone, which you omitted; 'tis true it is only an artificial one, but efficacious enough to deserve some Regard.

Eud. Let us confine our selves then to the simple vulnerary Stone. "As for the simple
"vulnerary Stone, says *M. Geoffroy*†, they take
"equal Parts of the Filings of Iron, and of
"pulverized Tartar, they make them in-
"to a soft Paste with Wine or *Aqua Vita*,
"and leave the Matter in Digestion before
"the Sun in the Summer, moving it from
"Time to Time, until the Whole be dried up
"intirely. They reduce the Mass into Pow-
"der, and after that soak it in Wine, making
"it digest again, and then dry it. They re-
"peat these Operations until they perceive no
"more Grains of Filings, and the Whole be

† Mem. de l'Acad. 1713. p. 187.

Upon the Earth and Minerals. 195

“ reduced into a very fine Powder. Then
“ with *Aqua Vitæ* they form Balls of it, which
“ they leave to dry in the Air, and to harden;
“ this is the simple vulnerary Stone, whose
“ singular Virtues they boast so much of for
“ healing Wounds and Ulcers.

“ They soak this Stone in Wine for some
“ Time, or in *Aqua Vitæ* or Urine; and with
“ this Dissolution they wash simple Wounds,
“ or else syringe them inwardly; sometimes
“ they spread the Stone itself upon the Wound
“ reduced into Powder to stop Hemorrhages,
“ and apply Compresses soaked in the same
“ Solution upon it, which they renew once in
“ twenty four Hours. They do the same
“ Thing for Ulcers, which it dries up and ci-
“ catrizes quickly.

Let us now, *Aristus*, only think of unveil-
ing the Mysteries of the Loadstone, if pos-
sible.



196 CONVERSATION XV.



CONVERSATION XV.

Upon the Loadstone.

Arist. **T**ILL you have discovered to me the Mysteries of the Loadstone, I shall be no more at Quiet than a Loadstone itself, which is not in its natural Situation, and which is seeking out the Poles of the Earth.

Eud. The Loadstone, that Mineral, whose Direction guides us without erring through unknown Ways even to the End of the World, and brings us home again loaded with the Stones of the East, and with the Gold of *Peru*, is nothing else, at least ordinarily, but a blackish and ferruginous Stone, which is found in Iron Mines, but harder than Iron itself. A certain Author ^u makes Mention of a white Loadstone, and that it is as strong as the best; but a white Loadstone is very rare.

Certainly this sort of Stone has astonishing Properties, and much more capable of striking a Philosopher than Gold, precious Stones and Diamonds; namely the Direction, magnetic Vortex, Attraction, Communication, Inclination and Declension.

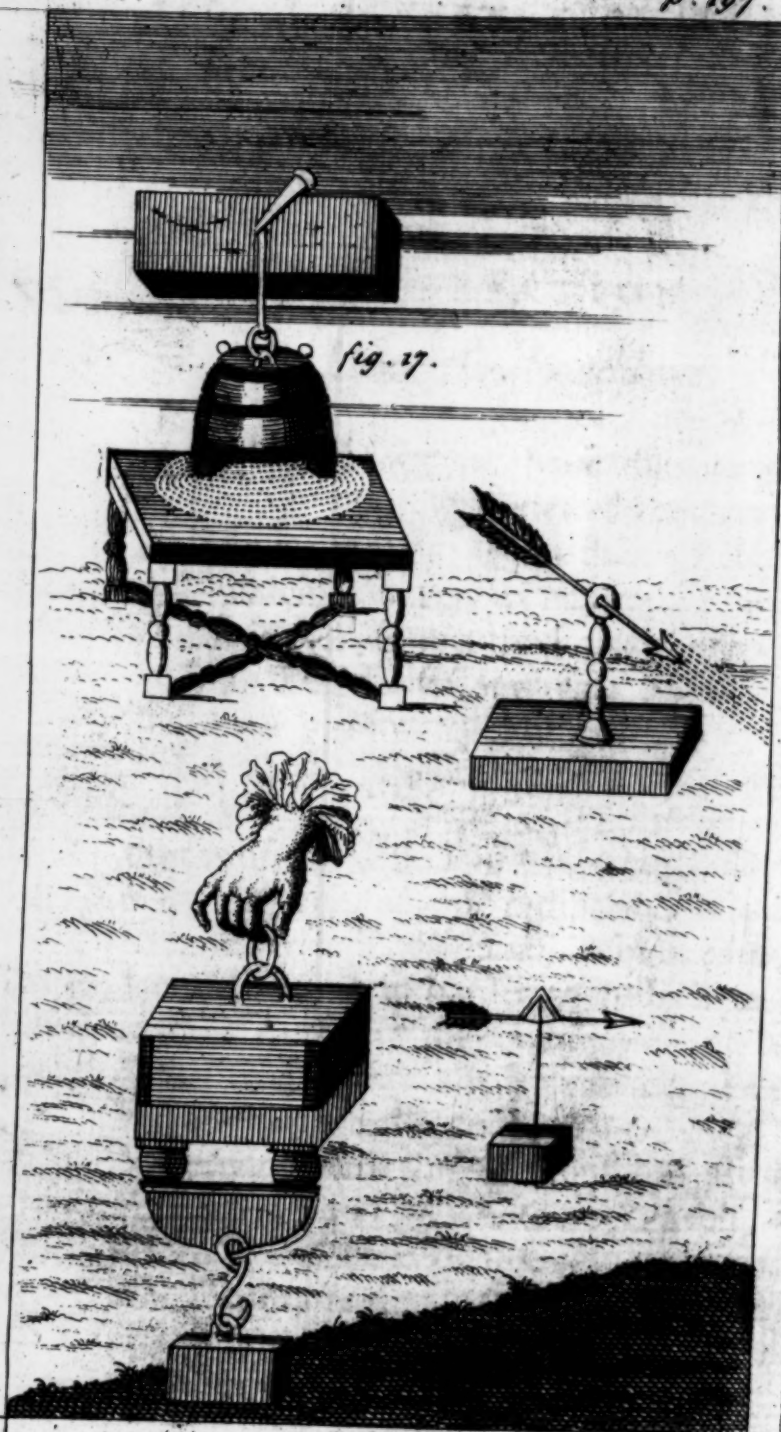
^u *Velfchius*, J. des Sçav. 29 Mar. 1677. p. 80.

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A Loadstone at Liberty and suspended by a Thread, seems to affect to turn always the same Sides toward the same Poles of the Earth; and this is what they call the Direction of the Loadstone. An imperceptible Matter incessantly circulates round it, issuing out of one of its opposite Sides, and entering again thro' the other, and leaving Traces, which represent its circular Motion, in the Filings of Steel or Iron scattered upon Paper, which they bring near it; this is the magnetic Vortex, *Fig. 17.* You know they call a Vortex some liquid Matter which circulates round about a spherical Body. The Loadstone, Iron and Steel being free and placed at a certain Distance, are attached to the Loadstone as of themselves; this is Attraction. They say that there is in the *Museum* of the Royal Society at *London*, a Loadstone which attracts a Needle at nine Foot Distance*. In the very Moment of this marvellous Union the Loadstone makes its properties pass at once into the Iron and Steel, into the Blade of a Knife, and the Needle of a Mariner's Compass; this is Communication. Should it approach to a Pole of the Earth, the Side which is nearest the Pole is bias'd and inclines toward the Earth; this is Inclination. Inclination is remarkably sensible in a Needle touched with the Loadstone. Finally, the Direction of the Loadstone, and of Bodies touch-

* Jour. des Sçav. 22 *Mar.* 1682. p. 79.

198 CONVERSATION XV.

ed with it, towards the Poles of the Earth is not so fixed but that they decline some Degrees towards the East, or towards the West; and this is the Declination of the Loadstone.

Arist. I am well apprized of these Wonders, neither am I weary of admiring them; but what is their Original, or what is the physical Cause, whose Action produces them? Upon this Head one has some Difficulty to explain one's self clearly.

Eud. It is a sort of subtile Matter, which running from one Pole of the Earth toward the other, penetrates the Loadstone and Bodies touched with it.

1. It is a sort of subtile Matter. For it is not the Loadstone; the Wonders of the Loadstone consist in divers Motions of the Loadstone itself, of Iron and Steel; and the Loadstone is not moved of itself, being only ineffectual Matter which does not properly move the Iron or Steel but they come in Search of it, even when it is immovable. What is then this Source of philosophical Prodigies? It must be agitated Matter, but imperceptible. It is, I say, agitated Matter, since it produces Motions of inanimate Bodies, Motions which depend upon the Stroke upon some Matter; it is imperceptible Matter; it does not affect the Senses. Now this imperceptible Matter is a sort of a subtile Matter, or only the Air. It is not merely the Air; the Air does not affect to

unite

unite two Loadstones. Have they lost their Vortex in the Fire? It is certain that the Air does not unite them. Therefore it is a more refined Matter, a sort of subtile Matter.

2. This Matter flows near the Surface of the Earth from one Pole toward the other: Being agitated as it is, it cannot have a Direction from Pole to Pole without flowing after that Manner. But it has a Direction from Pole to Pole; for it gives such a Direction to the Loadstone being at Liberty, and *M. de la Hire* having enclosed in a Stone some considerably fine Iron Wires, and Parallel to the Axis of the Earth, or placed in the Plane of the Meridian, at the End of ten Years found, that the Matter which animates the Loadstone, flowed from one End to the other of those Wires.

3. Lastly, this Matter penetrates the Loadstone. Present to a Loadstone a light Bed of Filings of Iron or Steel, scattered upon some Paper. Immediately a Vortex of Filings seems to issue out from the two opposite Sides of the Loadstone; a Vortex which cannot be formed but by a Vortex of subtile Matter that issues out of the Loadstone.

The surprizing Effects then of the Loadstone proceed from a sort of subtile Matter, which flowing from one Pole of the Earth toward the other, penetrates the Loadstone and Bo-

200 CONVERSATION XV.

dies touched with it. Which was to be proved.

But in Order to comprehend the Mechanism of this Matter, which they call magnetic Matter, let us make some Observations.

1. The Matter, which directs the two Extremities of the Loadstone toward the two Poles of the Earth, flows incessantly and rapidly from the one to the other of those Extremities; as one may observe by the Velocity with which it forms the Vortex of File Dust. Therefore there must be in the internal Part of the Earth a Fluid of the like Nature, which flowing from Pole to Pole makes itself free Passages in the Loadstone, while it is forming in an Iron Mine.

2. The magnetic Matter that issues out rapidly from one Extremity of the Loadstone, and is, no doubt, reflected by the Resistance of the Air, which increases in Proportion to the Velocity of the Matter that strikes it, circulates upon the Surface of the Loadstone: Why should not the Matter which is united toward a Pole of the Earth, and darted out into the Air, be reflected after the same Manner by the Resistance of the Air, and forced to return by circulating near both the internal and external Surface of the Earth? Thus you have a Vortex of magnetic Matter round about the Earth, as well as about the Loadstone.

3. Can one be astonished after this, that they look upon the Earth as a great Loadstone,
and

and upon the Loadstone as a little Earth, which has its Poles, Axis, Meridian and Equator?

Therefore they distinguish two Poles in the Loadstone, a South or meridional one, and a North or septentrional one. Those two Poles are the two Sides of the Loadstone, which turn as of themselves toward the Poles of the Earth. The Pole, which in the Mine lay Southward, is the meridional Pole; and that which faced the North, is the Septentrional.

4. If the Matter which circulates round about the Loadstone, could enter again by the Pole which permits it to issue out, it would not circulate. Consequently the same Parts of magnetic Matter do not find Access into a Loadstone but by the same Pole. Do they enter by the meridional Pole? They cannot enter by the Septentrional. If they enter by the septentrional Pole, they cannot enter by the Meridional. For which Reason a Loadstone suspended over the Surface of the Earth, cannot receive directly the Matter which passed through it in the Mine, and which returns by circulating, without being in an opposite Situation. Did its meridional Pole receive Matter coming from the South? It ought to face the North, in order to receive the same Matter on its Return. Hence the Pole which points to the North, is called the meridional Pole of the Loadstone, and the opposite Pole is called the Septentrional.

5. The

202 CONVERSATION XV.

5. The Pores of the Earth and Loadstone ought to have a particular Configuration, since they do not receive the same magnetic Matter but only by one Part, neither does it produce the same Effects in all Bodies. Has not the magnetic Matter itself its own Configuration?

M. Huygens conceived its Particles to be like so many Darts, and the Pores of the Loadstone like small Pipes, whose internal Surfaces was bestrewed with small flexible Hairs, inclining to one Side for letting the Fluid run, but always ready to resist and hinder its returning by the same Way: *M. Descartes* conceived those Particles as so many Screws turned round contrary Ways, and the Pores as so many Screw-Boxes formed in an opposite Manner, and fit for letting the Fluid run; the one only from South to North, and the other only from North to South. The first Opinion appears more simple, and the second more ingenious. But as a Thousand different Configurations of Parts and Pores may cause a magnetic Vortex, one can determine nothing upon this Head.

6. Does the magnetic Matter come from both Poles of the Earth, into both Poles of the Loadstone? *M. Descartes* believed it; and there is no solid Reason to prove the contrary. If the Matter did not come from both Poles, Bodies thrown upward under the Equator, being thrust more toward one Pole than the other,

ther, would they fall perpendicularly? A Loadstone being at Liberty, would it not be carried away by the Torrent of this Matter?

Arist. There seems to be nothing more needful to explain the Experiments of the Loadstone.

Eud. Well! I am going to make some very curious ones; you shall explain them.

In the first Place I hang up an excellent Loadstone by a Thread perpendicular to its Axis. — It is agitated, and appears restless, until its South Pole be turned toward the North, and its North Pole toward the South.

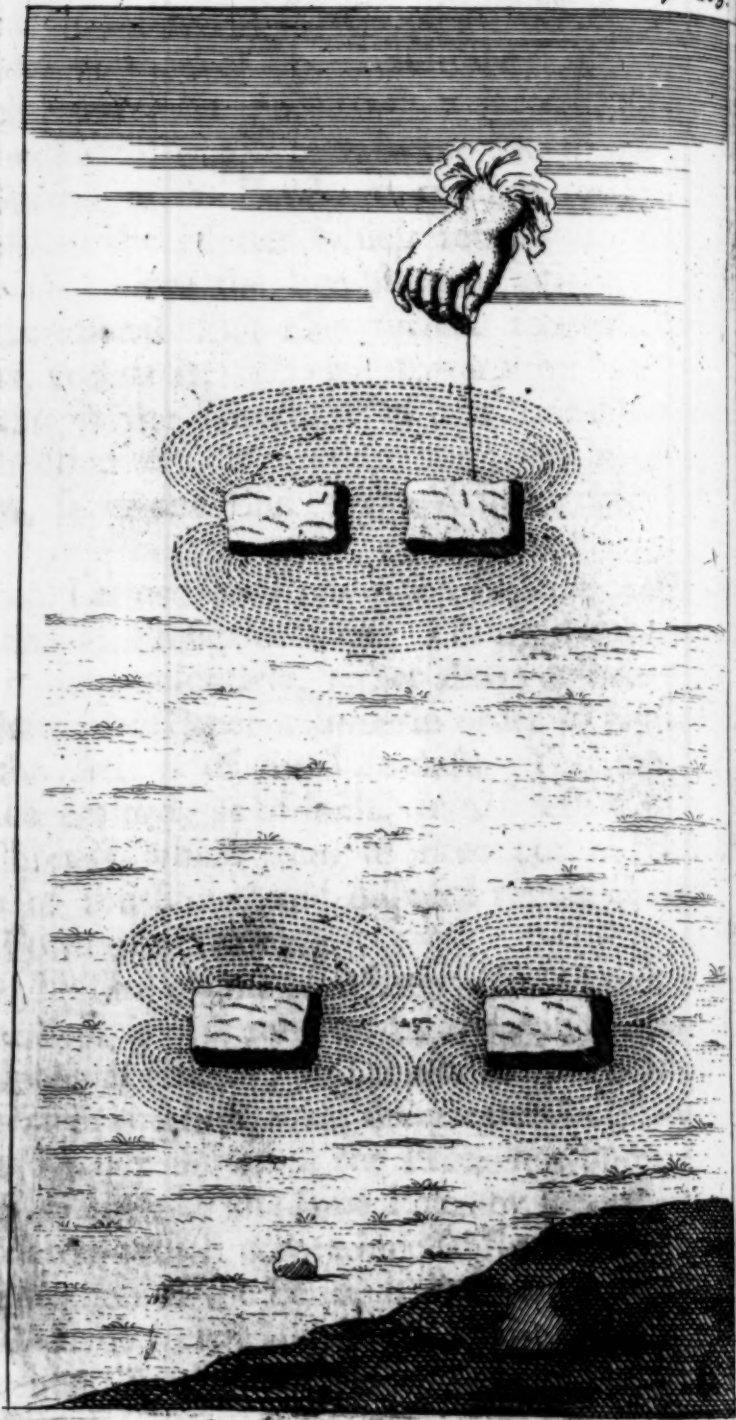
Arist. The fine Matter which flows rapidly from one Pole of the Earth towards the other, and which at first does not find in the Stone the Pole appointed to receive it, following its Direction, attempts in vain to enter, strikes, and thrusts irregularly. The Stone being struck and thrust in that Sort, yields to the Strokes according to their Force. Hence, this Agitation, and a kind of Restlessness. By Virtue of its being agitated in turning about, it presents at last to the Direction of the magnetic Matter the Pole destined for receiving it, and which did receive it in the Bosom of the Earth. The Matter finds therein a free Access, flows into it, penetrates the Stone, and passes through without pushing it more to one Side than another; and the Loadstone remains immovable; no more Restlessness. Draw it out of this Situation: Its first Restlessness is renewed

204 CONVERSATION XV.

ed and ceases by the same Reason. Now, the meridional Pole of the Loadstone, or that which faced the South when it was within the Earth, ought to face the North above the Surface of the Earth, in order to give free Access to the Matter which returns by Circulation. Thus the Loadstone is agitated till its meridional Pole be turned toward the North, and its Septentrional toward the South; and this is the Direction of the Loadstone; a Direction which guides our Vessels over Rocks, from one End of the World to the other.

Eud. Let us now strew upon Paper a pretty thin Bed of Filings of Iron. I bring the Stone near it perpendicularly, either above or below; I agitate the Paper a little in order to facilitate the Action of the File-dust. You see it at once divided, as of itself, into small circular Threads which seem to issue out of the Poles of the Stone, and disposed round about it in Form of a Vortex.

Arist. The magnetic Matter that issues out of the Pole, and is reflected by the Air, which encounters it directly, and resists so much the more as it is struck with the greater Velocity by the Matter united in the Pole, not finding Access to enter by the same Pole, by Reason of the Matter which comes incessantly, and the Configuration of the Pores, is divided into concentric Semicircles, some of them stronger, and others weaker, separated a little by the
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Opposition of the Air; and circulating upon the Surface of the Loadstone in Form of a Vortex, it comes in Quest of the Pole, which received it at first in its Way. It finds the Filings of Iron, penetrates them, and lays them along, because it flows in them more easily than in the Air, by Reason that the Pores of the Iron are more proportioned to the Configuration of its Parts, more solid, and less interrupted than the Interstices of the Air incessantly agitated with an universal Motion. Thus it describes the Figure of its Vortex; and the Eye being surprized, sees in the File-dust a Vortex formed all at once.

Eud. To the South Pole of this Loadstone suspended, I present the North Pole of another Loadstone which is free. The one attracts the other; and you would say that an agreeable Sympathy united them both.

Arist. In this Situation the Matter, which is darted out from one of the Loadstones, finds a free Access into the other, and is carried thither with extreme Velocity, driving out the Air from between the Loadstones. There is no more *Equilibrium*. The Air being driven out retires, and is contracted behind the Loadstones; being contracted it is dilated. In its being dilated, it pushes the Loadstones towards one another. The Loadstones being pushed, the one towards the other by opposite Forces, and finding less Force to overcome inwardly than outwardly, because there is nothing else
almost

206 CONVERSATION XV.

almost found between them but some very fine Matter which easily penetrates them; and because they are protruded by the external Air, both the one and the other yield to the Excess of Force, approach one another, and are united, by a real Impulsion to which moreover they give the Name of Attraction, and they remain attached together in one common Vortex, which one may see described upon some Filings of Iron or Steel.

Eud. Let us separate the Loadstones, and present the two Poles of the same Name to one another, the two Meridionals, or the two Septentrionals. The Loadstones seem to fly from one another. Would you not say that a secret Antipathy had suddenly succeeded to the strongest Sympathy?

Arist. The Matter which impetuously flows from one Pole to the other of the same Name, not finding therein any Access, because it is not the Pole prepared for receiving it, or which received it in the Mine, thrusts it back with all its Force out of its Vortex, and does it the more effectually because it moves with greater Velocity, until it find nothing more to straiten its Sphere of Activity. The Loadstones being protruded after this Manner towards opposite Parts, where they find contrary Forces less united, and Spaces more free, yield rather to the Excess of a foreign Force, than to the Motion of a secret Antipathy.

Eud.

Eud. Let us only use one Loadstone. I present to it a Plate of Copper; it does not attract it in the least.

Arist. The Matter that issues out of the Loadstone, with a Configuration proportioned to the Pores of the Loadstone itself, not finding in those of the Copper the same Disposition for receiving it, does not run into them, neither is it united in a sufficient Quantity, not to leave much Air between the Loadstone and the Copper. Hence, the Air which remains, and the Matter which does not pass through, repel the Copper. The Fluid, which passes through, and returns being reflected by the external Air, drives back the Plate, seconded by the Spring and Pressure of the Air: The Plate being impelled towards two opposite Parts by equal Forces, obeys them equally, and remains at Rest.

Eud. The Loadstone attracts neither Lead nor Wood, by the same Reason. But if I bring a Plate of Iron near it, the Iron comes and applies itself to it.

Arist. The magnetic Matter meets with the same Configuration of Pores almost in the Iron as in the Loadstone, which is found in Mines of Iron. It finds free Access, runs into them, and is united in a sufficient Quantity to drive out almost all the Air from between the Iron and the Loadstone. The Air being driven out, returns backward upon the Loadstone and the Iron. The Iron being violently propelled toward

208 CONVERSATION XV.

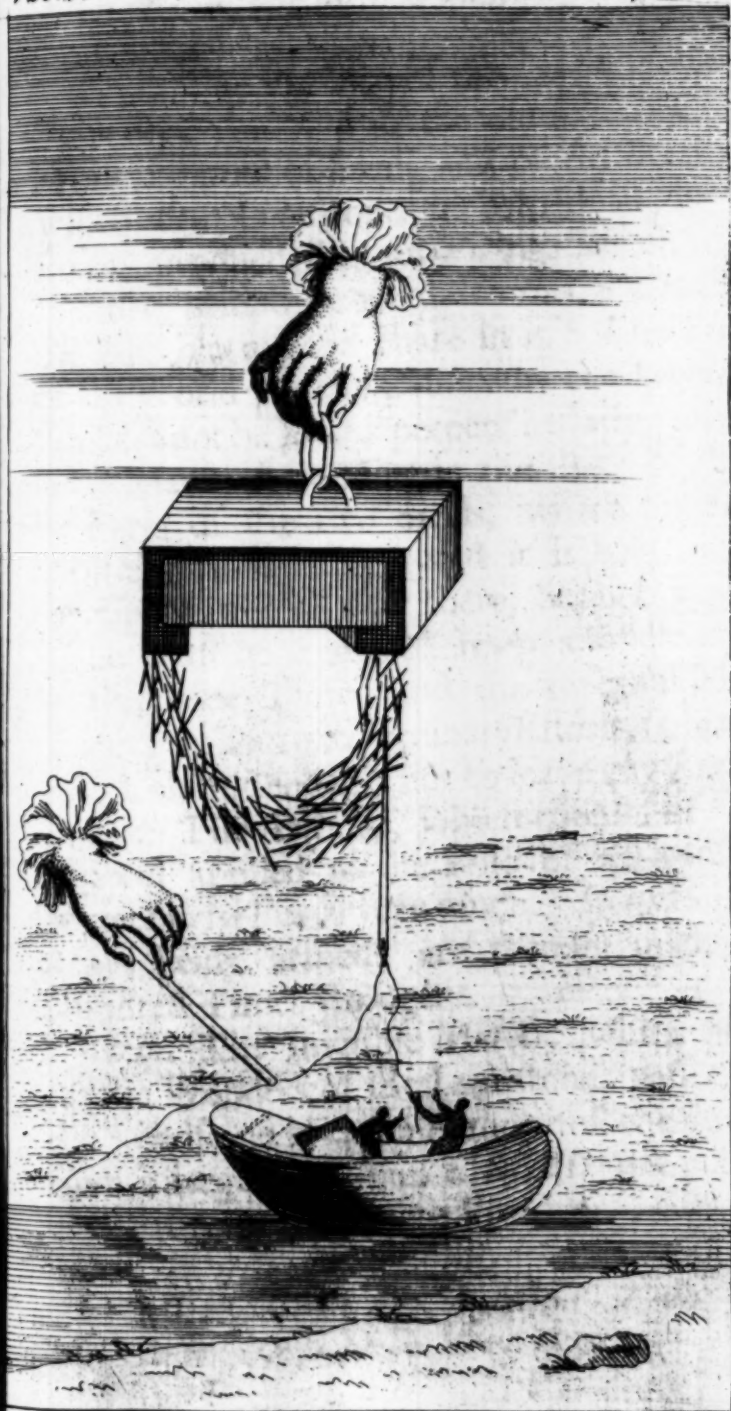
ward the Loadstone, without finding any Obstacle between the Loadstone and it, because it gives a free Passage to the magnetic Matter, follows the strongest Impression, flies toward the Loadstone, and lays hold on it, as one Loadstone lays hold on another.

Eud. On the same Principle one might see the same Diversion in Steel. But let us put a Loadstone upon Water in a little Boat of Pasteboard, and embark with it these little Figures; they are Toys and Play Things. Do not you observe the Loadstone itself, followed with the Toys, come swimming in Quest of the fixed Steel, which is presented to it.

Arist. Since the Air driven from between the Loadstone and the Steel, retires equally behind both, it thrusts equally the Steel toward the Loadstone, and the Loadstone toward the Steel. They both observe the Laws of Nature exactly; the Loadstone which is free comes attended with the Toys in Quest of the Steel, which is not so.

Eud. To this Plate of Steel attached to the Loadstone, I affix a Weight of 28 Pounds. The Weight cannot loose it from the Loadstone. This Loadstone equals that which *M. Huygens* made Use of ², and is not inferior to that which was offered to Sale for 5000 Livres in 1702, and which weighing only ele-

² Hist. de l'Acad. 1679. p. 184.



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ven Ounces did notwithstanding bear up 28 Pound of Iron *.

Arist. The Pressure of the external Air, the Fulness of the World, the immediate Contact of the *Lamina* of Steel, and of the Steel with which the Loadstone is armed in its two Poles, produce this surprizing Effect. The Pressure, which proceeds from the Gravity of the Air, has a good Share in it. The Fulness of the World† is the Cause why the *Lamina* of Steel cannot be loosed perpendicularly, without some Matter succeeding in the Place of the solid Parts of the two Steels, which touch one another immediately; and it is very difficult for any Matter to flow there, because a whole Plane must be separated from another almost at the same Time, and the external Matter cannot, without extraordinary Efforts, slide along with Celerity enough not to leave any *Vacuum*.

Eud. The Armour, which consists of Plates of Steel applied to the Pole of a Loadstone, augments its Force very much. Certain Loadstones being armed, are thereby made two Hundred Times stronger^a.

Arist. The invisible Matter, which produces the Wonders of the Loadstone, passes from the Loadstone into the Armour of the Steel, as from a larger Bed into a straiter one; it also passes therein with more Freedom, because the

* Hist. de l'Acad. 1702. p. 18. ^a Hist. de l'Acad. 1723. p. 102.

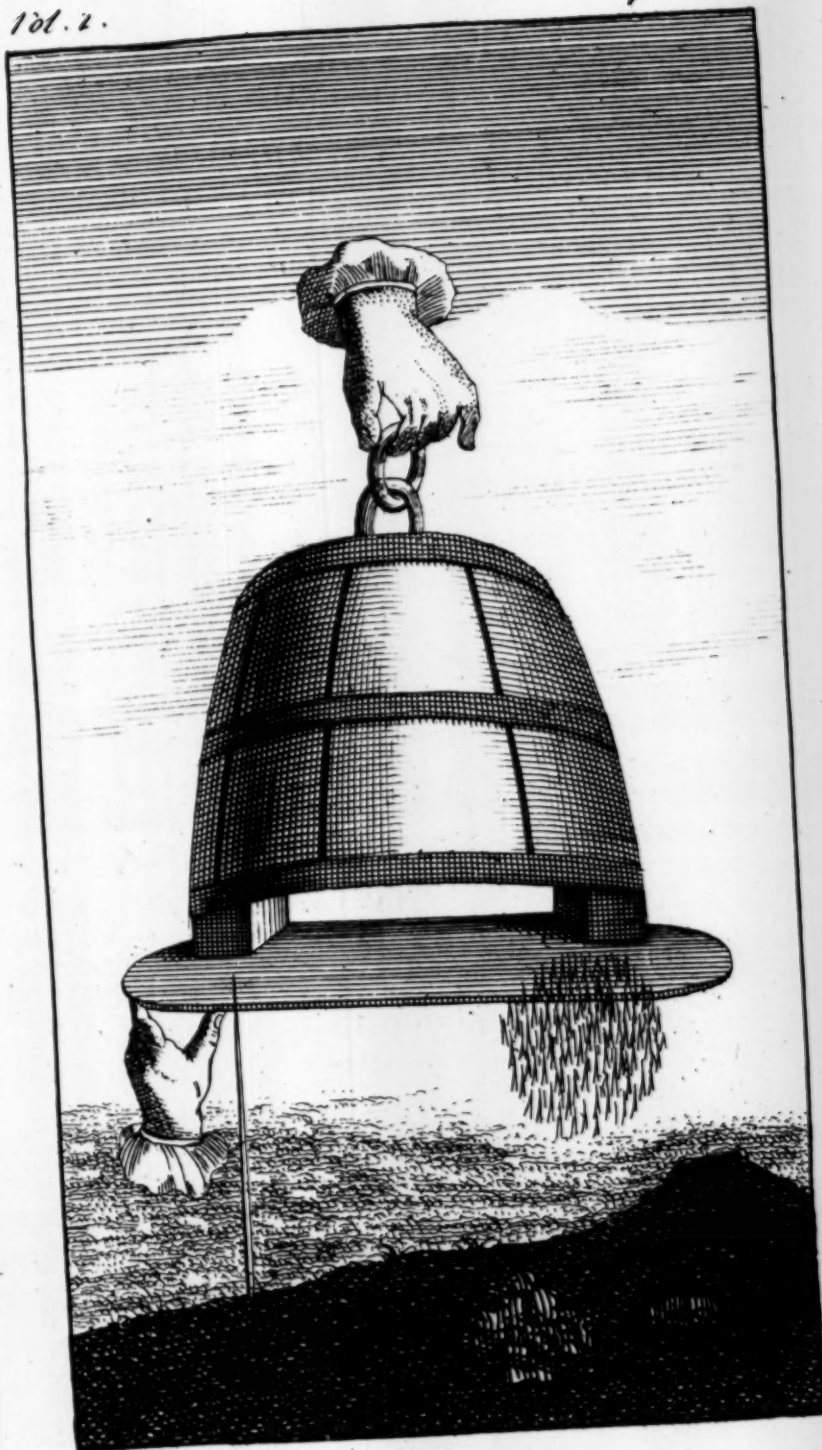
† Vide Notes CONVERSAT. V. and IX.

210 CONVERSATION XV.

Steel is of a Matter more stiff than the *Magnet*, which is a Stone. Hence the magnetic Matter accelerates its Motion, and its Excess of Motion is an Excess of Force. Moreover, the Steel being smoother than Stone, there remains less Air between the Steel and the Bodies which are immediately attached to it, than betwixt the Stone and those Bodies.

Eud. After this, need we be astonished if the Loadstone, to which I present Filings of Steel, becomes suddenly, as it were, bristled? What surprizes me is, that putting a *Lamina* of Copper between the Filings and Loadstone, the Filings are attached to the *Lamina* of Copper, without the *Lamina* being attached to the Loadstone. I slide the Loadstone over the upper Surface of the *Lamina*. You may see perpendicular Threads of Filings sliding along at the same Time upon the inferior Surface. What magical Charm holds them attached by one of their Extremities, and makes them go and return rapidly, as at the Pleasure of the Loadstone?

Arist. The *Lamina* of Copper is not attached to the Loadstone, because the magnetic Matter not passing easily enough through the Pores of the Copper, as we have said already, there remains much of this Matter and of Air between the Copper and Loadstone. But that which passes finding an easie Access into the Filings, runs abundantly into them, and drives out almost all the Air which is found between
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the *Lamina* and the Filings; no more *Equilibrium* of Forces at the opposite Ends of the small Parts of the Filings; the Air driven out becomes victorious, protrudes toward the *Lamina*, and holds them attached to it. Such is the invisible Bond. By the same Principle, whenever you slide the Loadstone toward one Part, the Air carries thither the Threads of the Filings. This, I think, is the Spring which presents to our Eyes the magical Diversions of the Loadstone.

Eud. I move the Loadstone a little from the superior Plane of the *Lamina*: The Enchantment ceases, and the Filings fall down.

Arist. When it is no more within the Vortex, at least not in a powerful Part of the Vortex of the Loadstone, the external Air is no longer sufficient to support it.

Eud. Let us lay aside the *Lamina* of Copper, and present to the Loadstone a sewing Needle; there it is suspended by the Point: What has made it of a sudden, so sensible?

Arist. That which carries the Filings of Iron, Steel, and Loadstone itself toward the Loadstone, and holds them attached to it, suspends the Needle upon the Loadstone, and keeps it suspended. The Air thrusts it toward the Loadstone, by repelling the magnetic Matter towards it. There is nothing to hinder its being attached to the Loadstone, because there is no more Air, or much less Air

212 CONVERSATION XV.

between it and the Loadstone; the *Equilibrium* being taken away, it only follows the Impression of the greater Force in its being attached by the Point.

Eud. Let us turn the Loadstone round the Needle of a Compass, placed horizontally upon an Axis, after such a Manner that it may turn round. The Needle goes round with the same Velocity. Would you not say that it was afraid of losing the Pole which attracted it?

Arist. One of its Extremities being continually drove by the expelled Air, which however returns upon it, while it is not equally repelled by the fine Matter which is alone, or almost alone, between it and the Loadstone, it must yield, and endeavour to wait on the Loadstone which flies away, by turning round upon its Axis.

Eud. If I make the Stone go round a contrary Way with the same Rapidity, the Needle returns and follows the Stone with the same Velocity.

Arist. The Needle, in returning, only follows the same Principle.

Eud. Let us put the Loadstone and Needle into Water. The Needle goes in Quest of the Loadstone, notwithstanding the Obstacle of the Water which it must cut every Moment, in order to come at it: The Reason is, because there is certainly Air in the Water, as we shall see, and consequently a subtile Matter which
expels

expels it, and disturbs the *Equilibrium* of opposite Forces, as without. The Air being expelled, but victorious in its Return, forces the Needle to retire toward the Loadstone. The Needle would discover the same Forwardness to unite itself to the Loadstone, and the same Restlessness in an Air-Pump, out of which one had pumped the Air, because some Air still remains, at least a subtile Air.

Shall we, *Aristus*, make a Whirligig go round, whose Axis is of Steel? It is permitted to Philosophers themselves to toy, when the Business is only to unravel Truth. I present the Plane of the Head of the Armour to the superior Extremity of the Axis. The Axis lays hold of the Plane, and is attached to it; and the Whirligig being supported merely by an invisible Force, turns round but the swifter.

Arist. The Whirligig rises like the Needle; the same Force produces two similar Effects. But why does the Whirligig continue to turn round? Because its perpendicular Direction is not opposed to the circular Motion, which it had before the Loadstone bore it up. If it turns round with a greater Celerity, that is because the Plane, which it touches, is more polished.

Eud. Let us forbear toying, and take again two Loadstones, the one stronger and the other weaker. I apply them both to a Piece of Iron by the two opposite Sides. With the

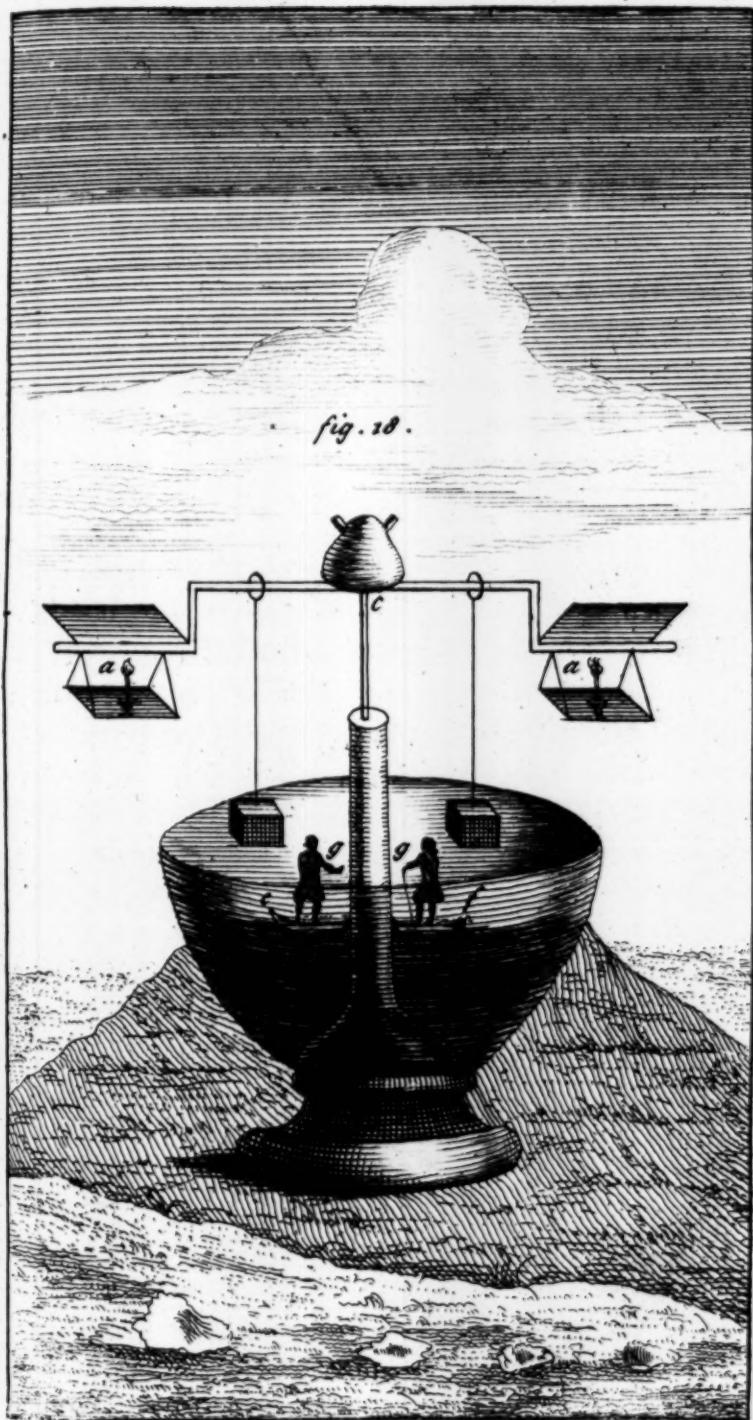
weaker I snatch away the Iron from the stronger, which however does not always happen. But how can the weaker prevail over the stronger?

Arist. When the Fact happens, it is probably because the stronger does not touch the Iron so exactly as the weaker, that consequently there remains some Air between the stronger and the Iron, and the Effort of the internal Air, for separating the Iron from the Loadstone, exceeds the Excess of Weakness which is found in the weaker. The weaker seconded by the Air, which remains between the stronger and the Iron, prevails so much the more effectually, because being within the Vortex of the stronger, it participates of the Force of the stronger, whose Vortex unites it firmly to the Iron. In short, withdraw the weaker from this Vortex, and it will quickly let the Iron fall.

Eud. One Experiment more, and we will finish this Conversation.

Fig. 18. I suspend a lighted Wax-Candle (*a*), under an oblique Plane (*b*) thin, moveable, and which can turn round upon a polished Axis (*c*). I hang a Loadstone upon the other Side (*d*), over the Water (*ef*). The Plane, Flame, and Loadstone turn round, and the Loadstone is agitated. Small enamelled Figures being (*g*) bored through with an Iron-Wire, follows it swimming.

Arist.



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Arist. The Flame makes the oblique Plane turn round, after the same Manner as the Wind makes the Sails of a Windmill to go round. The Plane, which turns round, carries along with it both the Flame which continues to make it turn round, and the suspended Loadstone. The Loadstone, which goes round, loses its Direction toward the Poles. The magnetic Matter strikes it, in order to restore it. Hence the Inquietude of the Loadstone. The Air being expelled from between the Loadstone and the Figures of Steel, drives the Figures toward the Loadstone. Hence their apparent Sensibility, or this Forwardness to follow it swimming.

Eud. Hitherto, *Aristus*, we have seen the wonderful Effects of Direction and Attraction; this Evening we will observe those of Communication, Inclination, and Declination.





CONVERSATION XVI.

*Upon the Communication, Inclination,
and Declination of the Loadstone.*

Eud. **I** Rub a Knife, according to its Length, from the Handle to the Point, by conducting it from one Pole of the Loadstone to the other. The Knife, which I have rubbed, lifts up Iron Nails, Keys and Needles: The magnetic Virtue has passed into the Knife, without ceasing to be in the Loadstone. Let us present to the Loadstone a Needle placed upon the Axis of the Needle of a Compass. The Needle has already its Poles turned toward the Poles of the World. I present a Pole of the Loadstone to the Point of a sewing Needle; it is there suspended perpendicularly by the Point. The other Extremity of this Needle draws to it a second by the Point, the second a third, the third a fourth, the fourth a fifth, the fifth a sixth, &c.

Arist. The magnetic Matter, which had made itself in the Iron, while it was with the Loadstone in the Mine, Pores much like those of the Loadstone, improves them by passing impetuously from the Loadstone into the Iron
or

or Steel, gives these Pores the Configuration which it retains in coming out of the Stone, consequently disposes them to receive it precisely on one Side, and to let it pass out precisely by another, gives its Direction to the magnetic Matter wherewith the Iron is penetrated, and by that Means makes two Poles: This is Communication, and thus the Iron and Steel, Needle and Knife become at once new Loadstones.

Eud. The Needle, Knife, and Rods of Iron or Steel assume the magnetic Virtue according to their Length; the Ends become Poles. Does the Loadstone touch one Extremity? The other is endued with a magnetic Virtue.

Arist. The Reason is, because the magnetic Matter, finding therein more solid Pores, Pipes, and Passages more proportioned to its Configuration, and less interrupted, wherein it must communicate less Motion than in the Air, whose Parts are more ramose, it flows in them more easily than in the Air itself. Hence the Rods of Iron or Steel being put into a Situation parallel to the Meridian, the Fire-tongs themselves become magnetic according to their Length, in receiving the Fluid which issues out of the Bosom of the Earth.

Eud. A Knife, that slides Cross-ways upon the Pole that endued it with a magnetic Virtue, loses sometimes its Virtue all at once.

Arist. The Matter, which finds the Parts of the Iron and Steel more flexible than those
of

218 CONVERSATION XVI.

of the Loadstone, enters impetuously into the Iron and Steel through the Pole prepared for letting it pass out; raises up again the Particles Cross-ways, the small Hairs which at first it had made to incline to one Side; changes the first Configuration of the Pores, and by that Means shuts up the Passage against itself.

Eud. By the same Principle, the Needle of a Compass loses its Virtue, when it is too long retained in a Situation parallel to the Meridian, but contrary to the Course of the magnetic Matter. You need but hold the North-Pole of the Load-stone applied to the North-Pole of a magnetic Needle, and it becomes Magnetic the contrary Way.

Arist. The Reason is, because the magnetic Matter finds the Particles of the Needle sufficiently pliable and flexible for receiving at once a contrary Arrangement and Configuration.

Eud. Sometimes in this Change the magnetic Virtue is only augmented.

Arist. That is, because the Particles of Steel being turned an opposite Way, thereby become only more flexible, and fitter for yielding to the Current of the Fluids.

Eud. Would you imagine that Thunder could give a new Direction to the magnetic Needle, as well as the Loadstone? But one Day all the Needles of an *English* Vessel, upon which the Thunder fell, immediately took a new Direction, and so constant, that they could not change it. The Pilot of the Vessel

fel resumed the same Course he had made, without knowing it, till the Pilot of another Vessel made him observe in the Direction of his Needles the new Phenomenon of the Thunder^b.

Arist. Probably the magnetic Matter being forced by the Violence of the Thunder to flow back impetuously through the same small Passages of the Needles, made the small Parts of those Ducts to take opposite Configurations and Directions.

This Phenomenon, *Eudoxus*, brings into my Mind the Obligation which the whole World is under to the *Portuguese*, who purposing to discover the *Indies*, found out, or improved at least, a Thing more to be esteemed than the Riches themselves of the *Indies*, that is the Compass^c. This Invention is so glorious to those who were the Authors of it, that in some Measure we owe to them the greatest Part of the Discoveries which have been made in different Parts of the World.

Eud. They pretend that the *Chinese* had the Use of the Compass, long Time before*. However that be; Will you believe it, *Aristus*? According to the Experiments of *M. de Reamur*^d, Iron gives a magnetic Virtue to Iron, without touching the Loadstone, and also to

^b Journ. des Sçav. 1 Mar. 1677. p. 61.

Hist. des Indes. Journ. des Sçav. 1666. p. 118.

le Comte, dernière Lett. du Tom. I.

1723. p. 81.

^c Maffée

* Le Pere

^d Mem. de l'Acad.

220 CONVERSATION XVI.

itself when it is broken. Being placed vertically it becomes magnetic, not only after a considerable Time, as Shovels and Pincers; or after many Years, as the famous Crosses of the Bells of *Aix* and *Chartres*; but in a Moment. Almost all the Tools, which cut or pierce Iron in a cold State, as Scissars, Bodkins, and Gravers, are immediately endued with magnetic Virtue; since whenever they have cut or bored Iron, they begin to be charged with Filings of Iron^e: When you break Iron by having bent and twisted it different Times in the same Part, you will find it become magnetic in the breaking; the two Ends where it is broken, attract Filings of Iron or Steel^f.

Lastly, a Bar of Iron placed vertically acquires two Poles in an Instant, The lower End attracts the Point of the Needle which ordinarily faces the South; and towards the upper End there is a Pole which attracts the North Point. The two Poles change, whenever the Bar happens to be in an opposite Situation.

Arist. It is very probable that the Iron is penetrated with a magnetic Matter, imprisoned, as it were, and that there are in the Iron several small Vortexes of this Matter, weak and irregular, which give little Strength to the Iron, because they do not concur to the same Effect. It is in Mines of Iron that the Load-

^e Mem. de l'Acad. 1723. p. 82, 83.

^f p. 92, 93.

stone acquires its Force; and Bodies which have the Virtue of Attraction, attract more Filings when they are placed upon some other Iron. If you remove from an Anvil magnetick Iron, which has charged itself thereon with Filings, immediately it loses its Force, and lets fall what it bore^s. Probably because the Iron has its Atmosphere, which augments its Vortex. The greater the Vortex is, the greater is the attractive Virtue. A weak Loadstone increases in Force in the Vortex of a stronger one^h.

This being granted; 1. When a Tool of Iron or Steel cuts or bores Iron, the Matter expelled from the disordered or contracted Pores of the Iron, is darted out into the Tool, whose Parts being harder, and more separated by the Effort of the Operation, present more free Pores or Passages to the magnetic Matter; and it gives the Matter which it encounters therein its Direction from one End to the other. Hence the Tool has its two Poles; and it becomes Magnetic.

2. When one breaks Iron after having bent it, the internal magnetic Matter being violently agitated by the Torture, finds Passages in the two Ends of the Fracture, is united in them, runs off, and being repelled by the Air, returns alternately with the Filings of Iron.

^s Mem. de l'Acad. 1723. p. 29.

^h P. 90.

Thus

222 CONVERSATION XVI.

Thus Iron becomes magnetic without the Help of the Loadstone.

3. Finally, when one places a Bar or Rod of Iron vertically, the magnetic Matter probably runs along through the Iron while it issues out of the Earth with Impetuosity, and by the Violence of its Action it makes two Poles, the one in the lower End, and the other in or towards the upper End.

Eud. The attractive Virtue of a Tool, which cuts or bores Iron, is augmented under the repeated Blows of the Hammer.

Arist. Under each Blow some new Matter being forced to penetrate the Tool, enlarges the open Passages, and opens itself new ones; and a more abundant Circulation increases the attracting Power.

Eud. After a certain Number of Operations and Efforts, it is augmented no more.

Arist. The magnetic Matter finding at last a sufficient Number of Passages in the Steel, it more easily follows the first, than it opens new ones for itself; and as the Vortex does not increase any more, the Force is not augmented.

Eud. Sometimes the Blows of the Hammer make Iron lose the Virtue of Attraction forthwith.

Arist. That is, because they immediately straiten or shut up the Passages of the magnetic Matter.

Eud.

Eud. Iron, which retains its Force, bears more Weight near a great Mass of Iron, than when it is near a Bar.

Arist. The great Mass, having a greater Atmosphere, yields more magnetic Matter, and consequently more Force.

Eud. An Iron-Wire, about the Thickness of one's Finger, and rendered magnetic by breaking, acquires so much the more Force, the greater Number of Places it is bent and twisted inⁱ.

Arist. More Passages are opened for the magnetic Matter.

Eud. Too many Inflections make the Iron-Wire lose its Force.

Arist. Too many Inflections expel the magnetic Matter, or at least stop its Passages.

Eud. An Iron-Wire struck with the Blows of an Hammer, does not become Magnetic.

Arist. The Wire being narrow and almost equally compressed in those Parts where it has received the Blows, has no longer any convenient Place left in it for the magnetic Matter, wherein it may be lodged, or through which it may pass.

Eud. But a large Bar becomes magnetic under the Hammer, if one strike it with the smallest End of the Hammer only in the Middle, or near one of the Edges of the Bar.

ⁱ Mem. de l'Acad. 1723. p. 94.

224 CONVERSATION XVI.

Arist. In this Case the expelled Matter still finds a Lodging in the Iron, and a Place which affords it a free Passage.

Eud. But why do those Tools become magnetic which cut Iron while cold, and not those which cut it while hot?

Arist. As the Fire dilates the Pores of red-hot Iron, the Point or Edge of the Tool does not straiten the magnetic Matter, nor Force it to pass into the Tool.

Eud. But finally the Tool, which cuts or bores red-hot Iron, loses its attractive Virtue.

Arist. That is probably because in the Action the magnetic Matter passes with more Facility into the hot Iron, and quits the Steel; or because the Heat disorders the Parts, and stops up many Passages of the Steel.

Eud. From these surprizing Effects of Communication let us pass, *Aristus*, to Inclination. Inclination is a Situation wherein one of the Poles of the Loadstone, or else of a Body touched with the Loadstone, inclines more than the other toward the Earth. This Property will be better manifested in a magnetic Needle, than in the Loadstone itself. Therefore let us place horizontally, upon two small Props, a Needle bored through the Middle, at right Angles, by a small Brass Wire, which serves to support it. The Needle is moveable, and in *Æquilibrium*; I make the Loadstone pass over it, from one End to the other, from North to South; the End which faces the
North,

North, or the meridional Pole of the Needle, far from pointing to the polar Star, falls and descends. The magnetic Needle, which guides our Vessels, is differently inclined in different Countries.

Arist. The magnetic Matter enters or comes out more easily, more swiftly, and more abundantly through the Poles of the Loadstone, than through its Equator, since there is a greater Force in its Poles. I say the same likewise of the Poles of the Earth; in short, the magnetic Matter circulates from one Pole of the Earth to the other. This being granted, when the Loadstone has passed over an horizontal Needle in Northern Countries, the Matter which issues out of the North Pole of the Earth, flows abundantly into the South Pole of the Needle. Now if the Matter pass more easily from the South Pole of the Needle into the North Pole of the Earth, or in greater Abundance from the North Pole of the Earth into the South Pole of the Needle, its South Pole ought to incline to the Horizon. The Matter which passes more easily from this Pole into the Earth, takes a Direction toward the Earth in its issuing out, and gives it to this Pole by striking it, and driving out more Air from between the Earth and it: The Matter which passes more abundantly from the Earth into the same Pole in circulating, produces the same Effect in its Entrance, it being reflected by the superior Air.

Eud. In a Word, if I place the North Pole of this Loadstone under the South Pole of the Needle, it is inclined to the Horizon. If I place the South Pole of the Loadstone under the North Pole of the Needle, it also is inclined in its Turn. Hence when our Vessels come from North to South, or from South to North, the Needle of the Compass is usually parallel enough to the Horizon under the Equator. But in Proportion as one advances from the Equator toward the North, the South Pole of the Needle is inclined; and in Proportion as one advances from the Equator toward the other Pole of the Earth, the North Pole of the Needle is inclined: A Situation conformable to that of the magnetic Matter, which descends or ascends obliquely toward the Poles, and is parallel to the Horizon under the Equator, as the Matter which makes the Vortex of the Loadstone, and which describes its Way and Direction upon the Filings of Steel. But finally what is the Declination of the Loadstone?

Arist. It is a Motion which makes its Poles diverge from North and South toward East or West.

Eud. In the Beginning of the last Age, the Declension at *Paris* was from six to eight Degrees from North to East; in 1640 about three Degrees^k; In 1650 betwixt five and six De-

^k Journ des Sçav. 1681. p. 19.

grees; in 1666 *Paris* was without any Declension^l. In 1681, the Declension at *Paris* was two Degrees and 50 Minutes from North to West^m. In 1684, four Degrees 10. In 1687 it was scarcely one Degreeⁿ. The 11th of *October* 1717, it was 12 Degrees 45 Minutes. The 16th of *July* 1728, it was 13 Degrees 50 Minutes. From the 16^h of *October* 1720, to the 3^d of *January* 1725, 13 Degrees^o. These Variations are observed toward the West and and in the *East-Indies*, as here^p. Some Places are without Declination. The Variations are different in different Places. Whence can this astonishing Phenomenon proceed?

Arist. It may proceed from the Changes which happen in the Earth. New Mines of Iron, old Mines exhausted, Mines differently situated, the Configuration of the Pores being changed toward the Surface of the Earth, by the Action of subterraneous Waters or Fires, all this may vary the Courses of the magnetic Matter; and the Variety of those Courses, their different Direction, ought naturally to cause a Difference in the Direction of the magnetic Needle. Should there come more magnetic Matter, or with more Force from one Side, the Needle would be carried that Way. Present to it two Loadstones, one of which is

^l Hist. de l'Acad. 1712. p. 20. Journ. des Sçav. 1681, p. 19.

^m Journ. des Sçiv. 1681. p. 19.

ⁿ Journ. des Sçav. 1687.

p. 93.

^o Mem. de l'Acad. 1724. p. 8. 1725. p. 5.

^p Hist. de l'Acad. 1685. p. 248.

228 CONVERSATION XVI.

stronger; and you may see it decline toward the stronger.

A *Spanish* Author, who was returning from *Peru* into *Spain*, having gone down into an excellent Mine of Loadstone, composed of two principal Veins which crossed one another, and one of which was extended from South to North, and the other from East to West, he discovered in this Mine a Line, which went from South to North, and was two Fingers broad, where the Needles fixed on the North Point. After that he placed them to the Westward of the Line, and they declined from North to East. At last he placed them to the Eastward of the same Line, and he saw them decline from North to West.

The same Author tells us of different Mines, which cause divers Variations. According to his Observations the greatest Part of those Mines is upon Coasts or in Islands; and consequently within Reach of acting upon the Needles of Vessels, which are not too far distant from them. If the Vessels are too far distant from them, there is no Cause of Variation, and the Needles fix toward the North.

According to the Observations of Father *Noel*, who travelled four Times to *China*.

1. At the *Cape of Good-Hope* the Declination of the Loadstone in 1667, was seven De-

q Dom. Francisco, Journ. des Scav. 1704. p. 364, 5, 6.
r Journ. de Trevoux 1712. p. 700.

grees 15 Minutes toward the West; in 1702, 12 Degrees 50 Minutes. In 1706, 13 Degrees 40 Minutes. In 1708, 14 Degrees.

2. The Variation of the Loadstone is different in different Places, and passes successively from West to East, and from East to West. The Declension toward the West decreases continually from *Lisbon* to the Height of the Island of *Fer*; whence the Declension passes to the East, and increases to about 360 Leagues from the *Cape of Good-Hope*. There it returns to the West as far as the Height of *Madagascar*; after that to the East, as far as the narrow Pass of the Sound; and at last to the West, passing from this Straight to *Ceilan* and *Goa*. Under the Meridian of the most southerly Cape of *Madagascar*, making a Tour toward the South Pole, the Compass declines more and more toward the West, 20 Degrees at the Latitude of 30 Degrees 40 Minutes, and 36 Degrees at the Latitude of 36 Degrees.

These Variations do not agree with the Meridians; and how can they be adjusted with the great Circle of magnetic Matter, in which the Mines of Iron and Loadstone, being spread abroad in several Parts, cause no Irregularities?

Eud. The Messieurs *de la Hire* have indeed represented the Globe of the Earth by a Loadstone formed round, of 100 Pounds, and almost a Foot and an half in Diameter, having an Equator and Meridians described upon its

230 CONVERSATION XVI.

Surface. The Needle of a Compass, placed successively upon those different Meridians, had sometimes a Declension toward the West, sometimes toward the East, and sometimes it had none at all ^s.

These Variations proceed probably from divers Mixtures irregularly diffused in this Stone. Now, is not the Earth and Loadstone still more fixed?

In the mean Time Dr. *Halley's* Discovery concerning the Declination of the Loadstone deserves our Attention. This learned *Englishman* found in a Voyage, which he made to the South Countries in 1700, in order to search out the Truth there, four different Places in which the magnetic Needle did not decline.

1. At $18\frac{1}{2}$ Degrees of West Longitude, reckoning the Longitudes of the Meridian from *London*, at two Degrees of North Latitude.

2. At four Degrees of West Longitude; at $37\frac{1}{2}$ of South Latitude.

3. At 10 Degrees of West Longitude; at $16\frac{3}{4}$ of South Latitude.

4. At 64 Degrees of West Longitude; at $31\frac{1}{2}$ of North Latitude.

When he had these four Points, he conceived an Idea of a crooked Line, pretty irregular, describing round the terrestrial Globe, having on one of its Sides the Places where the

^s Hist. de l'Acad. 1705. p. 8.

Declen-

Declension would be easterly, and upon the other those where the Declension would be westerly. He had the Pleasure of seeing that all his Observations, during his Voyage, agreed with so lucky a Thought; and he described this curve Line upon a Map.

M. Marchais in a Voyage to *Guinea* and *America*, *M. Houffaye* in an *East-India* Voyage, and *M. de May* in a *China* Voyage, found the Declensions of the Needle little differing from Doctor *Halley's* Chart. The supposed Line is moveable, and appears to advance always toward the West in Regard of us. A *French* Vessel which went to *China* in 1710, through the South Sea, found another Line without any Declension, which crosses the South Sea from North to South, much like a Meridian. Formerly there was no Declension of Needles observed at the *Cape*.

Arist. Doctor *Halley's* Notion appears to me very remarkable; but I think there are still wanting several Experiments for illustrating and confirming it.

Eud. There is so much the more Need of them, because in the same Place the Declination is not equally varied in equal Spaces of Time. If one perceive any Species of Progression, it is still very imperfect; and the Causes of the Declension which you have mentioned, will still probably prevail for some Time.

We shall say nothing of the Causes which destroy the magnetic Virtue. It is evident that

232 CONVERSATION XVI.

whatever may stop the Pores of the Loadstone, as Rust and Air itself, or may change their Configuration, as Fire, may destroy it. But before we conclude our Conversation, you must tell me why the greatest Part of precious Stones, Glass, Gum, *Spanish Wax*, Amber and Jet being rubbed, attract Chaff and other light Things, in some Sort imitating the Attraction of the Loadstone.

Arist. A violent Agitation, a sort of Heat caused by rubbing in the subtile or fine Matter, which penetrates the precious Stones, the Glass, &c. makes a kind of Vortex issue out of them, as out of the Loadstone, of Matter which passes more easily through Motes than Air, and whose Celerity at first compresses and expels the Air; but in a short Time the compressed and expelled Air is dilated and becomes victorious, drives the Chaff and Motes it meets with towards the precious Stones, &c. and applies them to the same so much the more effectually, as the Matter which darted from those Bodies after rubbing, has communicated and lost the Force which it had acquired in the rubbing itself; and this is the Attraction of precious Stones, Glass, Gum, *Spanish Wax*, Amber, Jet, &c.

Eud. Here are many philosophical Mysteries happily enough explained, *Aristus*; and these Illustrations will give some Light into what we shall say hereafter upon Gravity, and other Matters.

Arist.

Arist. Gravity is a thorny Subject, but curious; and I know an excellent Source, whence I could draw some Light, even before I hear you. I shall return to your Closet, as soon as possible; scarcely am I gone out of it, but the Relish of Truth calls me back again.



CONVERSATION XVII.

Upon Gravity.

Eud. I Am mistaken, *Aristus*, or you are satisfied with your Knowledge concerning Gravity. The Pleasure which Philosophers find in Truth, appears in your Countenance. It is not a chimerical Pleasure, but philosophical, modest and pure, which is felt and appears outwardly without any Alteration, either in the Body or Mind. I am impatient to share this Pleasure with you. Therefore tell me in the first Place what is Gravity.

Arist. The Gravity * of Bodies is the Effort which they make to tend toward a common Center

* The Gravity or Weight of Bodies is an accelerating Force; and this Gravity or Weight at the Surface, or at equal Distances from the Center of the Earth, is directly proportional to the Quantities of Matter contained in such Bodies. That Bodies press

234 CONVERSATION XVII.

Center; as Levity is their Effort to remove from it. For they call those heavy Bodies, which, whenever at Liberty, move towards a common Center as of themselves.

Eud.

press continually, or tend equally and uniformly to the Center of the Earth, and consequently, that this Gravity or Weight is an equally accelerated Force, is evident to Sense, as a most undoubted Matter of Fact; and it likewise farther appears from the most accurate Observations and Experiments.

First, That the accelerating Velocities, acquired by Bodies in their perpendicular Descent, reckoning from the Beginning of their Motion, are ever as the Times in which they are acquired, and the Spaces described as the Squares of the Times.

Secondly, That abstracting from the Resistance of the Air, the Space described by the perpendicular Descent of a Body in one Second of Time, is equal to 16,1 *English Feet*, and for any longer or shorter Time, as the Squares of those Times respectively.

Thirdly, That the Resistance of the Air being taken off, or allow'd for, the accelerating Velocities of all Bodies near the Earth's Surface, are exactly equal; the lightest Bodies descending as swift as the heaviest, and the least as swift as the greatest: The different Magnitudes, Densities, and particular Figures, Textures and Constitutions of Bodies, making no manner of Difference as to their Velocities of Descent; which in all Bodies alike are ever equal, in equal Times, and proportional to the Squares of those Times. Now since the *Momenta* or Quantities of Motion, in Bodies whose Velocities are equal, are as their Quantities of Matter, and since the accelerating Velocities of all Bodies descending by the sole Force of their own Weight, are likewise equal, by what has been just now observed; 'tis evident that the absolute *Momenta*, or Quantities of Motion in all such Bodies, are likewise as their Quantities of Matter: But these *Momenta*, or absolute Forces of descending Bodies, are nothing else but their absolute Gravities, by which they press continually, or tend equally and without Intermission to the Center of the Earth; and therefore this absolute Force of Gravity, or Weight in Bodies, is exactly proportional to their Quantities of Matter.

Corol. From hence it follows, that there are Vacuities or empty Spaces in Bodies. For since in Consequence of this Proportion,

Eud. Let us speak here only of the Gravity of terrestrial Bodies. We shall make our selves the better understood; and what we shall say will be of Use for comprehending the Gravity of all other weighty Bodies.

Arist. The Gravity of terrestrial Bodies is their Effort toward the Center of the Earth.

Eud. Do you only acknowledge one Sort of Gravity?

Arist. I distinguish two Sorts, the one absolute, and the other relative. I call absolute Gravity, the Gravity of a Body, considered precisely as the Gravity of that Body, without comparing it with the Gravity of any other, more or less weighty. I call relative Gravity, the Gravity of a Body considered with Relation to another more or less weighty.

Eud. But whence proceeds Gravity, whether it be absolute, or relative? Is the Cause external to the heavy Bodies? The Antients said, not; the Moderns affirm it; what think you?

on, the Weight of Bodies is proportional to their Quantities of Matter; and since upon the Supposition of an absolute *Plenum*, the Densities of all Bodies must be equal, or an equal Quantity of Matter every where contained in equal Spaces; 'tis evident, that upon this Hypothesis, the Weight of Bodies must be ever proportional to their Bulk or Magnitude, and there could be no Difference of specific Gravity in Bodies; which being most notoriously contrary to Fact, must evidently and demonstratively overthrow that Hypothesis of an absolute *Plenum*, upon which it is founded. *Morgan's Phil Princ. of Med.* p. 8.

Arist.

Arist. A Cause, which moves Bodies, is external to the Bodies; Bodies of themselves being only, each in particular, a Portion of Extension * indifferent to Motion or Rest, they have no Efficacy, no secret Quality, which should make them prefer Motion to Rest. Now the Cause of Gravity moves heavy Bodies; for whenever they are free, you see them pass from Rest to Motion, you see them fall: Therefore the Cause of Gravity is external to weighty Bodies.

Eud. This external Cause, which we do not see, and which notwithstanding immediately drives Bodies toward the Center of the Earth, must it not still be the subtile Matter; that Matter which appeared so new to you, and whose Idea seemed to quicken your Imagination in our first Conversations?

Arist. That which immediately impels sensible Bodies towards the Center of the Earth, is an insensible Body. It is a Body, since it impels, strikes and touches heavy Bodies. This Body is insensible; the Senses do not perceive it. This insensible Body is the Air, or subtile Matter: It is not the Air; we see Bodies descend being protruded by an imperceptible Force, so as no Body can suspect that the Air protrudes them. Invert into Quicksilver a Glass-Tube of six and thirty Inches, likewise full of Quicksilver: You may see the Quicksilver

* Rather of Substance or Matter, which is not Extension itself, but subsists in Extension, or extended Space.

descend

descend at least eight Inches; neither is there any Air above which can thrust it downward; the Air does not penetrate a Glass-Tube. Therefore the subtile Matter is the external and immediate Cause of the Gravity of Bodies.

Eud. I acknowledge it, and look upon this Reasoning as a physical Demonstration. But the inferior subtile Matter, which touches, thrusts, and immediately precipitates heavy Bodies, cannot give them a Direction toward the Center of the Earth, without having such another. Whence hath it one? This is what has not been demonstrated.

Arist. Probably it has it from the two Vortices † of the superior subtile Matter. In one of those two Vortices the subtile Matter turns round about the Axis of the Earth, and in the second, from one Pole toward the other.

Eud. Have not these two Vortices a great Appearance of being the Work of a lucky Imagination?

Arist. The first Vortex is not imaginary; I prove it. The Moon turns round the terrestrial Axis, always surrounded with subtile or ætherial Matter. For the Light of the Sun being reflected by the Moon strikes our Eyes. The Matter, in which the Moon swims, turns about with it; otherwise the Moon finding always some Resistance in the Liquid, which it must cut through and divide, would communicate and lose its Force every Moment, and

† See Notes CONVERSAT. XV. Vol. III.

238 CONVERSATION XVII.

at last would cease to run over the Heaven, as it has done with equal Pace for the Space of six Thousand Years past. Now the celestial Matter, which contains the Moon in its Bosom, cannot turn round with it about the Earth, unless the first Vortex be real.

The second Vortex is no more imaginary than the first. A magnetic Needle, as well as the Loadstone at Liberty, has two Extremities, two Poles, which seem always to search out the Poles of the Earth with some Inquietude. The Needle has not this Direction of itself, being only a Portion of Matter very indifferent of itself to all imaginable Directions. It must consequently receive it immediately from some agitated Matter, which has a constant Direction from one Pole of the Earth to the other, as you made me observe when you discoursed of the Loadstone. This Matter being agitated from Pole to Pole, is either the Air or some finer Matter, some subtile Matter, since it is an imperceptible Body. It is not the Air; the Air has no constant Direction, but is indifferently carried toward a Thousand Parts at the Pleasure of the Winds: Therefore it is a finer Matter, a subtile Matter, which circulates from Pole to Pole. And here is the second Vortex of subtile Matter as real as the first.

Eud. I must indeed at last acknowledge your two Vortices, which cross one another in such Sort, that the one seems to pass wholly under the other, as to penetrate it much after the same Manner as Water penetrates a long Pile
of

of Bullets which it crosses. But after what Manner do those Vortices give the subtile Matter, which immediately encompasses us, the Direction which it gives us toward the Center of the Earth?

Arist. 1. The Vortex, which turns round about the Axis of the Earth, gives the subtile Matter that is a little grosser, a Direction perpendicular to the terrestrial Axis; for according to the general Rule of Motion, when many unequal Bodies turn all round at the same Time about a common Center, those which have the greatest centrifugal Force, or which are fittest for Motion, prevail over the weaker, and precipitate them toward the Center of their Motion. 2. The Vortex which passes through the Poles, and carries along an infinitely fine Matter from Pole to Pole, gives this Matter a Direction almost parallel to the Axis of the Earth. The inferior and grosser Matter, having one Direction perpendicular, and another parallel, in order to observe the third general Rule of Motion, takes a Middle Direction, describes a Diagonal which directs it toward the Center of the Earth, and toward this common Center it thrusts all that it encounters in its Way; so that gross Bodies, which formerly were carried toward the Center of the Earth by a secret Sympathy, in order to rest quietly there, no more go or tend thither, but only as they are forced by the Efficacy of the finest Matter.

240 CONVERSATION XVII.

Eud. The subtile Matter which surrounds us, receiving two Directions, the one perpendicular to the Axis of the Earth, and the other horizontal or parallel, from the two Vortices which cross one another, takes a middle Direction which carries it toward the Center, whither its Action thrusts the Bodies which it encounters. Such, you say, is the Cause of Gravity. For my Part, I believe that the Action of the Stars, whose Light strikes our Eyes, and the Refractions which the subtile Matter suffers in the Atmosphere, may contribute to that, and second your Sentiment; the Hypothesis is ingenious: but an ingenious Hypothesis is an Hypothesis in the Air, and falls to the Ground, if it do not explain the divers Effects of Gravity.

In a Tube hermetically sealed, agitate and mix together pounded Glafs, Oil of Tartar, Spirit of Wine, and Oil of Peter; then let them alone, and you will quickly see those four different Species of Bodies disintangled from one another, separated, moved, and placed above one another, the Oil of Peter above the Spirit of Wine, the Spirit of Wine above the Oil of Tartar, and the Oil of Tartar above the pounded Glafs. What is it that makes this Discernment? Must it still be the subtile Matter? Would it seek out and disintangle the Particles of every Species in order to unite them again, and place every Species exactly in its Rank?

Arist.

Arist. The more Solidity Bodies have, the fewer are their Interstices; the fewer Interstices they have, the fewer free Passages they afford to the subtile Matter; the fewer free Passages they afford it, the more Blows they receive from it; the more Blows they receive from it, the more they are impelled towards the Center of the Earth; the more they are impelled towards the Center of the Earth, the more relative Weight they have; and in Proportion to their relative Weight, they are placed below others.

This being granted, the subtile Matter meeting with more Solidity in the pounded Glass than in Oil of Tartar, more in Oil of Tartar than in Spirit of Wine, more in Spirit of Wine than in Oil of Petre, strikes, impels, and precipitates the pounded Glass more effectually than Oil of Tartar, Oil of Tartar than Spirit of Wine, and Spirit of Wine than Oil of Petre. Hence the pounded Glass is placed at the Bottom, and over the Glass Oil of Tartar, &c. as the Earth, by the same Reason, is placed immediately under the Water, the Water under the Air, and the Air under the Fire. Thus the subtile Matter, making Use of the Motion which it has received from God, and which he continues to it, and striking divers Bodies more or less, according to the different Texture of their Parts, unravels a Chaos, and composes a kind of little World in a Glass-Tube.

242 CONVERSATION XVII.

Eud. You are going on to discover infallibly in your subtile Matter, why, the Bulk being supposed equal, Gold weighs more than Mercury or Quicksilver, Mercury more than Lead, Lead more than Silver, Silver more than Copper, Copper more than Iron, Iron more than Pewter, Pewter more than Marble, and Marble more than common Stones, &c.

Arist. The Texture of the Parts being more compact in Gold than in Mercury, in Mercury than Lead, in Lead than Silver, in Silver than Copper, in Copper than Iron, in Iron than Pewter, in Pewter than Marble, in Marble than common Stones, &c. the Gold receives more effectual Blows, more Force than Mercury, Mercury than Lead, &c. and it communicates and loses less of its Force, having less Surface in Proportion to its Mass. Hence Gold makes more Effort than Mercury, Mercury than Lead, &c. in order to withdraw itself from the Blows of the subtile Matter and to reach the Center of the Earth. Thus I think we have the Reason why Gold is heavier than Mercury, Mercury than Lead, &c.

Eud. You will have the Action of your imperceptible Matter, and the Texture of the Parts unequally compacted to make the Inequality of Gravity in Gold, Mercury, &c. But whence comes the Inequality of Velocity in the Fall of Bodies equally compacted, but of unequal Bulk?

Arist.

Arist. Those whose Bulk is greater, have less Surface in Regard of their Mass; having less Surface they encounter, in their Fall, fewer Parts of Air to drive away in order to reach the Center whither they tend; meeting with less Obstruction, they communicate less of the Force which they received from the subtile Matter; the less they communicate of it, the less they lose; the less they lose of it, the more they retain; the more Force they retain, the more swiftly they move. Thus you have the principle from which proceeds the Inequality of Velocity in the Fall of Bodies.

Eud. It seems, this Inequality of Velocity ought to be observed also in the Fall of the same Bodies, in the open Fields, and under a Vault.

Arist. Not at all; the Subtlety of the subtile Matter makes it find in a Vault Millions of free Passages in order to precipitate downward gross Bodies with the same sensible Celerity, as in the open Fields; and this has nothing in it which ought to surprize a Philosopher. Put a Plate of Copper between the Loadstone and Compass. Make the Loadstone turn about rapidly upon its Center. The Needle turns about with the same sensible Velocity, as if nothing had been put between it and the Loadstone. What makes it turn round? Is it not the Action of an infinitely fine Matter, which comes out of the Pores of the Loadstone, and passing through those of the Copper, gives the

244 CONVERSATION XVII.

Needle, of itself indifferent and quiet, a circular Motion, which makes it search out the Poles of the Loadstone, that flies from it, with so much Inquietude and Celerity?

Eud. Plausible Reasons never fail you; but agree to it at last, that Bodies melted or calcined ought to weigh less than before. For after having lost by the Violence of Heat, a Quantity of solid Particles which are exhaled in Smoak, they give less hold to the Strokes of the subtile Matter. Notwithstanding, Lead and Pewter being melted, and *Regulus Antimonii* being calcined, far from losing this Weight, acquire more.

M. Duclos of the Academy of Sciences reduced in a Marble Mortar, a Pound of *Regulus Antimonii* to Powder. This Powder they exposed to the Rays of the Sun in an earthen Pot, and then they set Fire to it by Means of a burning Glass. A thick and whitish Smoak came out of it; and an Hour after the Powder was reduced into a sort of Ashes, which, notwithstanding the Evaporation of a thick Smoak, was a tenth Part heavier than it was before^t. *M. Homberg* made the same Experiment with the same Success^u. Bricks also become more weighty in the Fire^x.

^t Chimie de L  meri, c. 5. Hist. de l'Acad. 1667. ^u Mem. de l'Acad. des Sciences, 1705, p. 94. ^x Bib. univ. & Hist. 1689, T. IX. p. 430.

Such Experiments seem made to take away from subtile Matter, light as it is, the Glory of causing the Gravity of Bodies.

Arist. Such like Experiments, in which subtile Matter itself has so great a Share, have nothing in them which ought to deprive it of the Possession it has of the Power of fixing us here, at least for some Time; without which the Curiosity of our Minds would make our Bodies travel into the Planets, before we attain to the Knowledge of the Earth itself. It is sufficient for this Sort of Experiments that a great Number of heterogeneous Parts, agitated in Bodies before melting or Calcination, are evaporated and dissipated by the Heat; or that losing by the excessive Agitation their Figure proper for Motion, they are intangled in one another, and fixed by the Inequality of their Particles, or by the Cold which succeeds the Heat. Being agitated before melting or Calcination, they supported and sustained the solid Particles against the Strokes of the subtile Matter, and blunted its Force. Being dissipated by melting or Calcination they support them no longer. Being fixed they receive themselves without any Reaction, the Strokes which render Bodies heavy. The want of Motion, or Fixation of the heterogeneous Parts contributes more to the Weight than did the agitated Parts, which are evaporated and dissipated. Hence this Excess of Weight in Bodies diminished in their Mass and Bulk. In short, the

246 CONVERSATION XVII.

Weight of Orpine, which is a sort of Colour for Painters, being fixed with Salt of Tartar is augmented a fifth Part; and any Body knows that cold Water is heavier than hot Water which is more agitated.

Does not this Reason satisfy? One may say that certain Corpuscles of Sulphur happen to be attached to Bodies, which increase in Weight, while they are melting or calcining; Corpuscles of the Colour of Ashes have been seen attached to the *Regulus Antimonii* when inflamed, let it be the Air or Fire that furnishes such Sort of Corpuscles.

Eud. You render whatever you please probable, and I must at last go into your Sentiment concerning the Cause of Gravity.

Arist. I believe, *Eudoxus*, it will not cost you much to think upon this Head as I do; you know whence I have drawn what I have said concerning it.

Eud. You imitate the Bees; you know how to improve and make your own what you find elsewhere.

Arist. Explain your self upon the Rules of Gravity; and you will tell me Truths much more agreeable than all your Compliments.

Eud. To explain my self upon these Rules, I shall first distinguish three Sorts of Centers; the Center of Bigness or Figure, the Center of Weight or Gravity, and the Center of heavy

Bodies. I call the Center of Bigness or Figure, that Point in heavy Bodies which is equally distant from all the opposite Points of the Circumference. I call the Center of Gravity, that Point in a heavy Body which is situate after such a Manner that the opposite Parts which surround it are in *Æquilibrium*, whether they be equally distant from this Point or not. Hence the Centers of Bigness and of Gravity are not always united in the same Point; they would not be so in a Ball half Iron, and half Ivory. Finally, the Center of heavy Bodies is a common Point whither those Bodies tend, as of themselves; such is the Center of the Earth.

Imagine now a strait Line drawn from the Center of Gravity, to the Center of heavy Bodies; this is called the Line of Direction, because it directs, in some Sort, the natural Motion of heavy Bodies toward their common Center. Is a Body removed from this Center? It ascends. Does it draw near it? It descends. This is sometimes by a plane vertical or perpendicular to the Horizon, and sometimes by an inclined Plane. This being granted, let us see Bodies descend, and we shall always find them faithful in observing certain Rules prescribed by Nature.

Rule I. If the Center of Gravity cannot descend, the heavy Body does not descend. But whenever the Center of Gravity can descend, the Body descends; because the

248 CONVERSATION XVII.

Parts, which are round about the Center, are in *Æquilibrium*, joined and fastened in some Sort with the Center.

Rule II. Does the heavy Body descend freely? It never leaves the Line of Direction; why? Because the Cause of Gravity, which gives it a perpendicular Direction, endeavours to maintain it therein, and no Reason removes it from it; the opposite Parts, which surround the Center of Gravity, being all in *Æquilibrium* by the first Rule.

Rule III. Is not the Descent perfectly free? The heavy Body moves as little as it can from the Line of Direction; since the Cause of Gravity gives it every Moment (by the second Rule) a perpendicular Direction, which would carry it toward the Center by the Line of Direction, if no Obstacle turned it aside from this Line and the Center.

Rule IV. Should the Center of Gravity not be in the Center of Bigness, the first would always be lowest when the Body descends; as it will always be highest when the Body ascends; because it being in that Case in the most solid Part, is also in a Part most proper for Motion.

Rule V. Let an heavy Body descend freely or not, by a vertical Plane, or an inclined one, its Motion is accelerated in the Fall; for being struck by the repeated Blows of the subtile Matter, it acquires every Moment more Force than it loses. Accordingly the Shock is augmented

mented in Proportion to the Height from which a Body falls. But after what Manner is the Motion accelerated? It follows nearly the arithmetical Progression of odd Numbers, 1, 3, 5, 7, &c. So that if in the first Instant it run through a Space of one Foot, in the second it runs through about three Feet, in the third five, &c. according to the Observations of *Galilæus*, and Father *Sebastian*.

Thus according to the Experiment of Father *Riccioli*, a Ball of Wood, of an Ounce and a half, falling from the Height of thirty five Inches into one Scale, elevates a Weight of five Ounces put into the other Scale; from the Height of 140 Inches, a Weight of 20 Ounces; from the Height of 315 Inches, a Weight of 45 Ounces; and from the Height of 560 Inches, a Weight of fourscore Ounces². Therefore, &c.

In a Word, if by the Force acquired successively in the first Instant the Body runs thro' one Foot, it ought, retaining almost the same Force, to run thro' about two Foot the second Instant; since almost all the Force acquired in the first acts during all the second. The same Body ought to run through one Foot more by the new Force which it acquires in the second Instant. Therefore it ought to run through about three Foot in the second Instant, and five Foot in the third by the same Principle, &c.

² Astron. Ref. Journ. des Sçav. 24. Jan. 1667. p. 17.

250 CONVERSATION XVII.

Rule VI. When the Motion of a Body is accelerated to a certain Degree, it is accelerated no more; because it then withdraws and snatches itself from the Strokes of the subtile Matter with so much Velocity, that it receives no more Impression than is necessary for its descending by an uniform Motion with as much Celerity as the subtile Matter.

Rule VII. A Body which descends upon an inclined Plane, descends with less Celerity than on a vertical Plane: The vertical Plane does not sustain it. It is in Part sustained by the inclined Plane, which in some Measure renders the Force of Gravity useless. Thus the Stroke of a Body, which comes upon an inclined Plane to strike you, hurts you more lightly, and so much the more lightly, as the Plane is the more inclined.

At the first Opportunity let us enliven our Philosophy a little with resolving some Problems, whose Solution ought to be the Consequence of what we have both said, in this Conversation.

CONVER-



CONVERSATION XVIII.

Wherein several Problems upon Gravity are resolved.

Eud. **W**E know that the Earth is spherical. Let us imagine it bored through from one Point of its Surface to the opposite Point; and let us place a Man in the Bosom of it. Let this Man have his Center of Gravity in the Center of heavy Bodies. Will he have Need of any Prop to support him?

Arist. No certainly, since the Feet and Head will be equally propelled toward the Center. But whether will his Feet or his Head be uppermost?

Eud. Without his being crooked he will have both Feet and Head uppermost, since he will have his Feet and Head equally distant from the Center of heavy Bodies. But what Method would you take to make him ascend and descend at the same Time?

Arist. Let him move his Head from the Center, his Feet will approach to it, and he will, in some Sense, ascend and descend at the same

same Time; since to approach to the Center is to descend, and to move from it is to ascend. But I suppose that this Man having ascended as far as the Surface of the Earth, is found amongst the Antipodes. How does he remain attached like them to the Surface of the Earth, the Soles of his Feet being diametrically opposite to ours, and his Head elevated toward Heaven as we are.

Eud. This is because the subtile Matter, which surrounds the spherical Earth, impels them as it does us, and gives them as well as us a perpendicular Direction toward the Center of heavy Bodies. But if the Cause of Gravity equally surround the whole Globe of the Earth, the Surface of Liquors ought to be convex; yet you would say that it is a Plane.

Arist. It is convex indeed, although its Convexity is insensible; for its Parts being equally pressed toward the Center of the terrestrial Globe, they ought all to approach it equally, and consequently make an Arc, all the Points of which being equally distant from a common Center compose a convex Surface. But if Bodies are thus pressed every where toward the Center of the terrestrial Globe, how are two perpendicular Walls parallel?

Eud. It being supposed that the Earth is round, they are not indeed really parallel; for if both the one and the other should descend to the Center by a perpendicular Line, they would be united together. But if the Point
of

Problems upon Gravity resolved. 253

of a Needle should happen to be immovable in this perpendicular Line, what Weight could it sustain?

Arist. Being placed below the Center of Gravity, it might support an immense Weight; since upon this Supposition the Center of Gravity could not descend. But why does an immense Weight move without Difficulty divers Ways, when the Center of Gravity is suspended in the Air?

Eud. Because in that Case you have neither the Inequalities of a rugged Plane to destroy, nor the Force of Gravity to overcome. But what would happen, if the Center of Gravity were neither suspended nor supported?

Arist. It is evident that it would fall; since the Cause of Gravity would push it downward, and nothing would hinder its Fall; and in its Fall it would carry along with it the rest of the Body, according to your first Rule of Gravity.

Eud. You see, no doubt, in this Principle, why in the Motion of two footed Animals the Body inclines and is biaſſed sometimes to the right, sometimes to the left.

Arist. This is to the End that the Line of Direction always passing through one Foot, while the other is in the Air, the Center of Gravity, from which the Line of Direction proceeds, may be sustained by this Foot. If the Center were supported by nothing, it would fall, and carry along with it the two footed
Animal,

254 CONVERSATION XVIII.

Animal, whether rational or not, to the Ground. But pray, what is it that teaches the little Birds perched upon a Tree in the Night-Time to hold fast the Branch precisely with one Foot, to draw up the other Foot under their Feathers, to carry their Head on the other Side, and hide it under the Wing, in order to sleep quietly?

Eud. It is Nature which teaches them, to the End that the Line of Direction may pass through the Foot which grasps the Branch, and that the Center of Gravity, supported by this Foot, may not disturb them, nor oblige them to interrupt their Sleep, and to fly away, in order to avoid falling.

Arist. It is Nature also then, which by secret Lessons teaches Porters and crook'd-backed Persons to bend themselves forward, when they have a considerable Weight upon their Back; or to bend backward when they carry a Weight before them, as Persons do who are in very good Plight of Body, or Women big with Child.

Eud. Nature makes them sensible that they ought to take this Situation, that the Line of Direction may pass through the Legs, and that the Legs may support the Center of Gravity; without which one might see frequent Falls more dangerous than diverting. But when good Manners incline the upper Part of the Body, and bow the Head forward, why does the

Problems upon Gravity resolved. 255

the natural Mechanism, as well as good Manners, advance one Foot?

Arist. They advance one Foot thro' which the Line of Direction may pass, and which supports the Center of Gravity, lest by an Excess of good Breeding one should throw one's Face upon the Earth, as they infallibly do, who without any Support, having both their Feet against a Wall, attempt to take up a Pin, or gather a Flower at their Feet.

Nevertheless in a four footed Animal, in a Horse for Example which gallops, the Center of Gravity being toward the middle of his Belly, seems to be sustained by nothing, yet he does not fall. Why?

Eud. In a Horse which gallops, the Center of Gravity, as well as the solid Diagonal wherein it is found, is sustained by two Legs, the right Fore-leg, and the left Hind-leg; or by the left Fore-leg, and the right Hind-leg; since both the one and the other always bearing alternately upon the Earth, support the solid Diagonal which goes from a right Leg to a left one, and to which the Center of Gravity corresponds.

Can you tell me with the same Facility why Bodies, whose Base is very large, can remain inclined with the greater Safety?

Arist. Because while the Line of Direction passes through the Base, the Center of Gravity being supported by the Base cannot fall; and so long as it cannot fall, the Parts surrounding

256 CONVERSATION XVIII.

rounding it remain faithfully attached to it, by the first Rule of Gravity. Hence the famous Tower of *Pisa*, whose inclined Top seems to threaten Ruin every Moment, always stands firm, and dares the Efforts of Gravity and Wind.

Eud. I adhere to your Sentiment upon this Head. But upon a Plane I give a right Direction to a Bowl, whose Center of Gravity does not coincide with the Center of the Figure: Will the Bowl turn aside or not?

Arist. It will turn aside; for the half of the Bowl, in which the Center of Gravity is not, having less Mass, will lose more of its Velocity, and for want of Velocity will force the other half, which ought to move more swiftly, to turn aside; much after the same Manner as the fixt Point, which is at the End of a *Radius* or Spoke, constrains the other Extremity every Moment to leave the right Line, in order to describe the Arc of a Circle.

Let us suppose now that the Center of Gravity, and the Center of Bulk or Figure, are the same Thing in the roundest Bowl that can be made. I place it upon the Edge of an horizontal Plane perfectly smooth: What happens?

Eud. The Bowl, without your impelling it the least in the World, will go as of itself, but is protruded by the subtile Matter, towards the Middle of the Plane; because the Middle of the Plane will be nearest to the Center of the Earth.

Problems upon Gravity resolved. 257

Earth. For all the Lines or *Radii*, from the Middle to the Extremities of the Plane, will be so many Tangents, which will remove more and more from the Center of heavy Bodies; so that if one should walk upon this Plane from the Middle towards the Extremities, or from the Extremities towards the Middle, one should descend or ascend incessantly upon an horizontal Plane. This is my Answer, I wait for yours.

I throw a Cat from the third Story into the Street; the first Instant of its Fall it has its four Feet upward; yet it falls upon the four Feet without any Hurt. What is it that gives it so safe a Direction in the Time of falling?

Arist. That is what I would willingly learn from your Mouth.

Eud. The Cat being suddenly seized with a kind of natural Fear, bends the Back-Bone, advances the Belly, stretches out Feet and Head, as if it attempted to recover the Place whence it came; and this gives the Feet and Head the greater Force of a Leaver. In this extraordinary Motion the Center of Gravity ascends above the Center of Figure; but not being sustained it soon descends; in descending in order to place itself below the Center of Figure, according to the fourth Rule, it turns the Belly, Head and Feet of the Cat towards the Earth; so that at the End of the Fall the Cat finds itself at the Ground upon its four Feet,

258 CONVERSATION XVIII.

and only runs the more swiftly: Thus you have the Problem explained.

Now I fill a Pail with Water; I plunge a Staff into it, one of whose Extremities is in the Middle of the Bottom; between the other Extremity of the Staff and the Handle of the Pail I insert the Blade of a Knife, which leans horizontally upon a Table or Plane: Will the Pail fall?

Arist. The Pail cannot fall, unless the Blade be inclined; the Blade cannot be inclined, unless the Staff in the Middle of the Pail describe an Arc of a Circle, elevating its lower End toward the Table or Plane; the Staff cannot ascend after that Manner, unless the Pail ascend with the Water; the Staff, Pail and Water cannot ascend, unless the Center of Gravity ascend; the Center of Gravity cannot ascend, since the Cause of Gravity thrusts it toward the Center of heavy Bodies, and no Force pushes it backward: Therefore the Pail of Water will not fall.

You know better than I do, that the Pail will not fall: But do you know what Method must be taken to make a Bridge in the Air without Pillars, upon which one might walk without ascending or descending, although in walking one always described an Arc of a Circle.

Eud. The Plan of that is very easie. Make a Vault of Stones in the Air, equally distant from the Center of the Earth, equally compressed

Problems upon Gravity resolved. 259

pressed by the Cause of Gravity, and equally supported by one another. Let the Vault encompass the whole Earth, as the Ring of *Saturn* encompasses that Planet, and thus you have your Bridge in the Air: You may walk upon it without ascending or descending, since you will always be equally distant from the Center of heavy Bodies.

Arist. The Walk would be new; but I should find more Pleasure in hearing you discourse here of the Vibrations of the Pendulum, or of this Billiard-Ball suspended.

Eud. Here is a Pendulum at Rest in a perpendicular Line, or Line of Direction. I remove it from this Line, carry it to the Right, and then leave it to itself. The Gravity makes it fall, as it were by a sort of inclined Plane. In its Fall it accelerates its Motion (by the fifth Rule of Gravity). Having by that Means acquired more Force than is necessary for regaining the Line of Direction, from which I removed it, it passes beyond it and ascends to the left, so long as its acquired Force can overcome the Resistance of the Air and of Gravity. In ascending to the left, it describes a smaller Arc, than in descending, because it meets with more Resistance. In descending, it had only the Air to drive away; in ascending, it has both the Air to repel, and the Gravity to overcome. Being forced to yield, it falls back from a less elevated Part than the first Time; it again accelerates its Motion proportionally,

260 CONVERSATION XVIII.

portionally, and passes beyond the Line of Direction. Having fallen back from a less elevated Place, it ascends still to a less Height, because it has acquired less Force. It falls back still, being impelled by the Cause of Gravity; and by alternate Vibrations, which continue to diminish, it passes and repasses the Line of Direction, till, after having most exactly observed your Rules of Motion and Gravity, it rests at last in the Line of Direction, from which I withdrew it at first.

The Vibrations of the same Pendulum, whether greater or smaller, always happen in equal Time, at least in the Judgment of the Senses. Remove two equal Pendulums unequally from the Line of Direction; then leave them at Liberty; you may see them form the same Number of Vibrations in the same Space of Time. Whence can that proceed? Because the same Pendulum, when it makes greater Vibrations, makes them proportionally with greater Velocity. In a Word, it descends from a greater Height, and describes an Arc which approaches nearer to the perpendicular, and consequently it descends more swiftly, accelerates its Motion, and runs through a greater Space in the same Time. Hence the Vibrations of the same Pendulum, whether greater or smaller, are sensibly formed in equal Times; and Clocks with a Pendulum, or which have a Balance, are the most exact; because all the Vibrations of the Balance or Pendulum being of the same

Dura-

Problems upon Gravity resolved. 261

Duration, they are fittest for dividing the Time into equal Parts. Thus nothing is more exact than the Clock, which you see in my Closet. Its Motion however seems to me too precipitate to Day; because it admonishes me to finish a Conversation, in which I find the most exquisite Pleasure. But at last, after what we have said, one may easily comprehend what respects Gravity and its Effects. Mechanics have already shewed them us in solid Bodies, when we were speaking of the general Principle of Mechanicks; whenever you please we will see them in liquid Bodies. I shall be pleased first to know your Opinion concerning Liquidity, and then I shall tell you mine concerning the Gravity of liquid Bodies, and last of all we shall dispute concerning the *Æquilibrium* of Liquors.





CONVERSATION XIX.

Upon the Nature of liquid Bodies.

Eud. **W**HAT is a liquid Body? What is Liquidity? What is the Cause of it? You are going, *Aristus*, to clear up this Matter, and my greatest Pleasure is to see the Truth come from the Mouth of a young Person, who discovers so constant a Zeal for it in a Time and Age, wherein Fables have so many Charms.

Arist. Upon this Head I shall only tell you the Opinion of *Eugene*. I call a liquid Body, said he to me yesterday, a Body whose Parts yield, without any sensible Resistance, to the Effort which I make in order to separate them, and which takes all Sorts of Figures without any Difficulty †. Such are the Air, Water, Brandy, Wine, Milk, &c.

What

† A Fluid is a Body whose Parts yield to any Force impressed, and by yielding are very easily moved one amongst another. Whence it follows, that *Fluidity arises from this, That the Parts do not strongly cohere, and that the Motion is not hindered by any Inequality in the Surface of the Parts*, as it happens in Powders. But the Particles of which Fluids consist, are of the same Nature with the Particles of other Bodies, and have the same Properties;
for

On the Nature of liquid Bodies. 263

What is Liquidity then? It is, continued he, a continual Agitation of insensible and divided Parts; suspend this Agitation, and the liquid Body is hardened; by that Means Water becomes Ice in Winter. Restore this Agitation to the insensible and divided Particles; the least Effort separates them; no more is required but to give them new Directions: Thus the hard Body becomes liquid, and Ice is no longer any Thing but Water.

Thus Experience sufficiently discovers a continual Agitation of insensible Particles in Liquids. For in a Word, Sugar and Salts are dissolved in Liquors, and Liquors receive the Colour, Taste, and specific Virtues of Barks and medicinal Plants. This is not done but by the Disorder and local Transportation of their Particles. The insensible Particles of Liquors cause this Disorder and Translation; they only cause it by Motion; they only give their own Motion in order to cause it: Therefore they must be in a continual Agitation. Hence

for Liquids are often converted into Solids, when there is a more strong Cohesion of them, as in Ice. On the contrary melted Metals give us an Instance of a Solid changed into a Fluid.

Fluids agree in this with solid Bodies, viz. That they consist of heavy Particles, and have their Gravity, proportionable to their Quantity of Matter in any Position of the Parts.

If in the Liquid itself that Gravity be not sensible, it is owing to this, that the lower Parts sustain the upper, and hinder them from descending: But it does not follow from thence, that the Gravity is taken away; because a Liquid contained in a Vessel will press down the End of a Ballance, which carries the Vessel in Proportion to its Quantity. *Vide Gravesande, p. 133.*

264 CONVERSATION XIX.

the Mixture of Wine and Water is made with so much Quickness, that you would believe the Water suddenly changed into Wine.

But whence proceeds, demanded I, this continual Agitation of insensible Particles? In a Word, what is the Cause of Liquidity? I see two Causes of it, answered *Eugene*, the one internal, and the other external. I find the first in the cylindrick, elliptick, or spherical and polished Figure of the Particles of liquid Bodies; and the second in the rapid Motion of the subtile Matter, which meeting in its Way with Particles of a Smallness and Figure so susceptible of Motion, communicates it to them incessantly; without which the Air itself, which encompasses us, would in a short Time become a solid Body, wherein every one would be much astonished to see himself immovable, as in a sort of Niche or Hole.

Therefore, said he again, it is the subtile Matter which gives Liquors the Efficacy they have in dissolving so many solid Bodies. But why does not this matter dissolve them equally without Liquors? Without Liquors, replied *Eugene*, this Matter, by Reason of its extreme Smallness, finds in those Bodies too free Passages, and passes through without disordering or hurting any Thing, at least sensibly; or being too feeble for making itself a Passage, it turns aside without doing any Damage. But in Liquors, it is charged with an Infinity of grosser and more solid Particles; being charged
after

On the Nature of liquid Bodies. 265

after that Manner, it makes a Bulk which finds less Access into the Pores, unites more Forces, strikes more violently, shakes and breaks the Bonds which hold the Parts united together, and at last dissolves the solid Bodies, so as to reduce them to a Liquor. Thus Water alone passes rapidly under a Bridge, and is broken against a Bark, without damaging either the Bark or Bridge; but is it charged with grosser Bodies, Pieces of Timber on Shoals of Ice? It shatters the Bark, overturns the Bridge, and carries Destruction and Desolation every where.

According to your Principles, replied I, all Bodies ought to be changed and corrupted sooner in Liquors than in the Air. Nevertheless Cherries, Nuts, Apricocks, and Citrons are less preserved in the Air than in *Aqua Vitæ* and dissolved Sugar.

If the Liquor, answered *Eugene*, cannot, because of its Thickness or Figure, penetrate into the Pores of a solid Body, it cannot dissolve it; it only preserves it from the Impressions of the external Air, and maintains it against the Efforts of the internal Air, which continually endeavours to break by its Spring, the small Pores which retain it as it were imprisoned in the solid Body. Is the Liquor filtered too easily in a Body? It breaks few Bonds, Parts or Fibres; it causes little Alteration in it. When it insinuates itself into the Interstices charged with Salts, and those Salts find themselves intangled
in

266 CONVERSATION XIX.

in them like so many small Wedges, without being able to disengage themselves, by Reason of the Solidity of the Parts which surround them; these small Wedges only give Consistence to the Parts which contain them, and which they contain in some Sort; they hinder the fine Particles of the Liquor from dividing those of the solid Body, or the Spring of the internal Air from breaking them. By that Means these Salts preserve Fruits, as common Salt preserves Meat.

This being granted, the Brandy penetrates too easily, or does not sufficiently penetrate certain Bodies, so as to damage them: If it contains Cherries, Nuts, Apricocks, or Citrons with Sugar, it carries the Salts of the Sugar into an Infinity of Pores; those Salts being sunk like so many small Wedges, without being able to extricate themselves, only serve to give Consistence to the Parts, which are between them; they secure them from the Action of the subtil Matter, Air and fine Parts of the Liquor. Thus Confits of Cherries, Nuts, Apricocks, and Citrons, are preserved in Liquor; they lose nothing in it but their Bitterness; the Liquor only sweetens them; being imbibed with Salts, which strike the Palate agreeably; far from being corrupted, they are rendered only the more delicious, the most rigid Philosophers themselves being Judges.

Your sweet Meats, replied I smiling, appear to me to have an exquisite Relish; I love them

so much the more, because you have, as it were, seasoned them with Philosophy. But a certain Quantity of Water dissolves precisely a certain Quantity of common Salt. The same Quantity of Water will however dissolve still a determinate Quantity of Sugar. How is this Problem explained upon your Principles? 1. The Particles of Water, answered *Eugene*, by their Agitation drive and expel from the Interstices or Pores of different Salts the Air and subtile Matter; they penetrate into them as so many small Wedges, divide, break and dissipate the Parts. Here is the Secret of dissolving. 2. The same Quantity of Water only dissolves a certain Quantity of common Salt. Why? Because the Points of the Water being blunted, by Means of their striking against the Parts of this Salt, find no more Access into its Pores. 3. The same Water does not yet cease to dissolve a determinate Quantity of Sugar. Here is the Reason: The Particles of Water, tho' their Points be blunted by dissolving the Salt, are still fine enough for entering with some sort of Violence into the Interstices of the Sugar, whose Pores are larger: But as they are blunted more and more, they become too thick for penetrating into the Sugar; and the Sugar receives no more impression from them. Here is, I think, the Solution of the Problem.

But, replied I, some Uneasiness always accompanies Curiosity. I don't know if I sufficiently understood from those Principles how
liquid

268 CONVERSATION XIX.

liquid Bodies sometimes lose their Liquidity; why, for Example, Blood let out of the Veins settles and coagulates. The Liquidity ceases, said *Eugene*, in Proportion as the Motion ceases, and the Motion is lost either by the Evaporation of the finest Parts, or by the Communication, or Mixture of certain Bodies, which by their Figure grapple, fasten, and retain the agitated Particles of liquid Bodies. Is the Blood let out of the Veins? The finest Parts evaporate, and others communicate their Motion to the Air; the Air is full of Spirits of Nitre, which creep into the Blood, contract its Parts, and dull their Motion. Thus the Motion is lost; the Blood, which carried Life into the whole human Body, thickens, coagulates and settles; thus it is useless. *Eugene's* Sentiment concerning Liquidity seems to me too natural not to be adopted.

Eud. I adopt it as well as you, and nothing agrees better with my Opinion concerning the Gravity of liquid Bodies. Some Propositions will express my Sentiments upon this Head the first Opportunity.

CONVER-



CONVERSATION XX.

Upon the Gravity of liquid Bodies.

Arist. **Y**OU had the Patience to hear me last, *Eudoxus*; I will have the Pleasure of hearing you to Day. Do not fear being interrupted.

Eud. Your Eagerness, *Aristus*, animates me to explain my self.

PROPOSITION I.

“ Liquors weigh †; since they afford some
“ Hold to the Cause of Gravity, or to the
“ Strokes of the subtile Matter, which thrusts
“ them, and gives them its Direction toward
“ the Center of the Earth.

By the same Principle the Air itself ought to have Weight, but less than sensible Liquids.

† Fluids agree in this with Solids, *viz.* That they consist of heavy Particles, and have their Gravity proportional to their Quantity of Matter, in any Position of the Parts.

PROPO-

270 CONVERSATION XIX.

PROPOSITION II.

“ In Liquors, the Weight of the superior Parts is communicated to the inferior Parts ||.

Those being impelled by the Cause of Gravity ought to impel these.

PROPOSITION III*.

“ If the Imagination divide Liquors of the same Species into Parts, Beds, or Surfaces of the same Bulk; those Parts, Beds, or Surfaces weigh proportionally as they are farther distant from the superior Surface, and nearer the Bottom.

Because in Proportion as they are nearer the Bottom, and farther distant from the superior Surface, besides the Impression which they always receive immediately from the subtile Matter, they are thrust towards the Center of heavy Bodies by the greater Number of heavy Parts, which cannot pass through freely, where the subtile Matter alone would pass, without making some Effort.

|| The lower Parts sustain the upper and are pressed by them, and this Pressure is in Proportion to the incumbent Matter, that is, to the Height of the Liquid above the Particle that is pressed; but as the upper Surface of the Liquid is parallel to the Horizon, all the Points of any Surface, which you may conceive within the Liquid parallel to the Horizon, are equally pressed.

* See Note on PROP. II.

Thus

On the Gravity of liquid Bodies. 271

Thus Sea Water is so much the heavier, the more it approaches the Bottom. They fasten to a sounding Lead, which is of a considerable Weight, and fastened to the End of a very long Cord; they fasten I say, to the sounding Lead a Glass Bottle, cylindrical, oval or round, empty, stopped with a sealed Stopple of *Spanish* Wax, and closed up with all possible Exactness. The empty Bottle, carried along by the Weight of the Sound, descends into the Depths. Draw it up again, and you will be surprized to see, at least sometimes, the Bottle almost full of clear Water extraordinary saltish^a. How did this Water, clear and so saltish, enter into the Bottle? Because the Bottle by Means of its descending, has been found in Beds so weighty, that in the excessive Compression a Quantity of fine, but solid Parts of Salt have made a Passage for themselves through the Pores of the Bottle, and those Points of Salt have carried off into the Bottle a Quantity of Particles of Water, strictly fastened and united with them.

^a I saw a Person who made this Experiment. The Bottle had descended about 200 or 225 Fathoms.

PROPOSITION IV.

“ Divide Liquors into liquid Columns, uniform and perpendicular: The absolute Weight of every Column will answer to its Height.

It is so much the greater, the higher it is; the higher the Column is, the greater Number has it of Parts or Beds; and by the third Proposition every Part, every Bed weighs more in Proportion as it is farther distant from the superior Surface, and nearer the Base.

Arist. Well, for once, *Eudoxus*, I shall have the ill-natured Pleasure of surprizing you in a Fault. From a Tube quadruple in Height and full, there would flow in an equal Time a quadruple Quantity, or four Times more Liquor; since the Cause of the Flux, or the Gravity would be quadruple, and the Effect answers to the Cause which produces it. Nevertheless from a quadruple Tube, there only issues out in an equal Time a double Quantity, or twice as much Liquor^b.

Eud. 'Tis true, there issues out only a double Quantity; but the Effect is nevertheless quadruple, as its Cause is. For a double Quantity of Liquor does not flow in equal Time, but with double the Velocity; and the flowing of a double Mass with double the Ve-

^b Hist. de l'Acad. An. 1668.

locity is a quadruple Effect. This Flowing, this Effect, is the Motion which results from two Degrees of Mass, and two Degrees of Velocity; and this Motion is four Degrees, since Motion is measured both by the Velocity and the Mass, and is the Product of the one multiplied by the other.

Should a Force of one Degree make one Inch of Water issue out in an Instant, a Force of four Degrees will only make two Inches run out in an Instant; for two Inches of Water flowing in an Instant, and consequently with a double Velocity, or two Degrees, afford four Degrees of Motion, if you multiply them by one another; and these four Degrees of Motion are an Effect which answers to a Force of four Degrees.

Arist. If a Force of one Degree make an Inch of Liquor run out of a Tube in an Instant, is it not natural that a Force of four Degrees make four Inches run out in an Instant?

Eud. Not at all. A Force of four Degrees would produce an Effect of 16 Degrees; for the four Inches of Liquor would not issue out in an Instant, but with a Velocity of four Degrees, which multiplied by the four Inches of Liquor, would afford 16 Degrees of Motion. But a Force of four Degrees does not produce an Effect of 16 Degrees; the Force or Cause is not less than its Effect. Therefore though a Force of one Degree make an Inch of Liquor run out of a Pipe in an Instant, it is not natu-

274 CONVERSATION XX.

ral that a Force of four Degrees make four Inches of it run out in an Instant. After this you may give your self up to the ill-natured Pleasure of seeing me in an Error.

Arist. I love better to indulge the Pleasure of seeing at last why I was deceived.

Eud. Let us go on to explain my Sentiment.

PROPOSITION V.

“ While the absolute Gravity of the Columns of a Liquid makes them tend downward, all their insensible Parts thrust one another every Way, toward all the imaginable Parts of the Universe*.

For, 1. The Motion or Agitation, which makes the Liquidity of liquid Bodies, forces their insensible Parts to thrust one another after that Manner. 2. The inferior Parts being compressed by the Weight of the superior, like

* *The Pressure upon the lower Parts, which arises from the Gravity of the superincumbent Liquid exerts itself every Way, and every Way equally.*

Which follows from the Nature of a Liquid, for its Parts yield to any Impression, and are easily moved; therefore no Drop will remain in its Place, if whilst it is pressed by a superincumbent Liquid it is not equally pressed on every Side; But it cannot be moved on Account of the neighbouring Drops, which are pressed in the same Manner, and with the same Force, by the superincumbent Liquid; and therefore the first Drop is at Rest, and equally pressed on all Sides, that is, in all Directions.

Corol. Hence it follows, that *all the Particles of Liquids* are pressed equally on all Sides, and therefore *are at Rest*; and that they do not continually move among themselves, as several have supposed. *Gravesande's Elem. V. I. p. 136.*

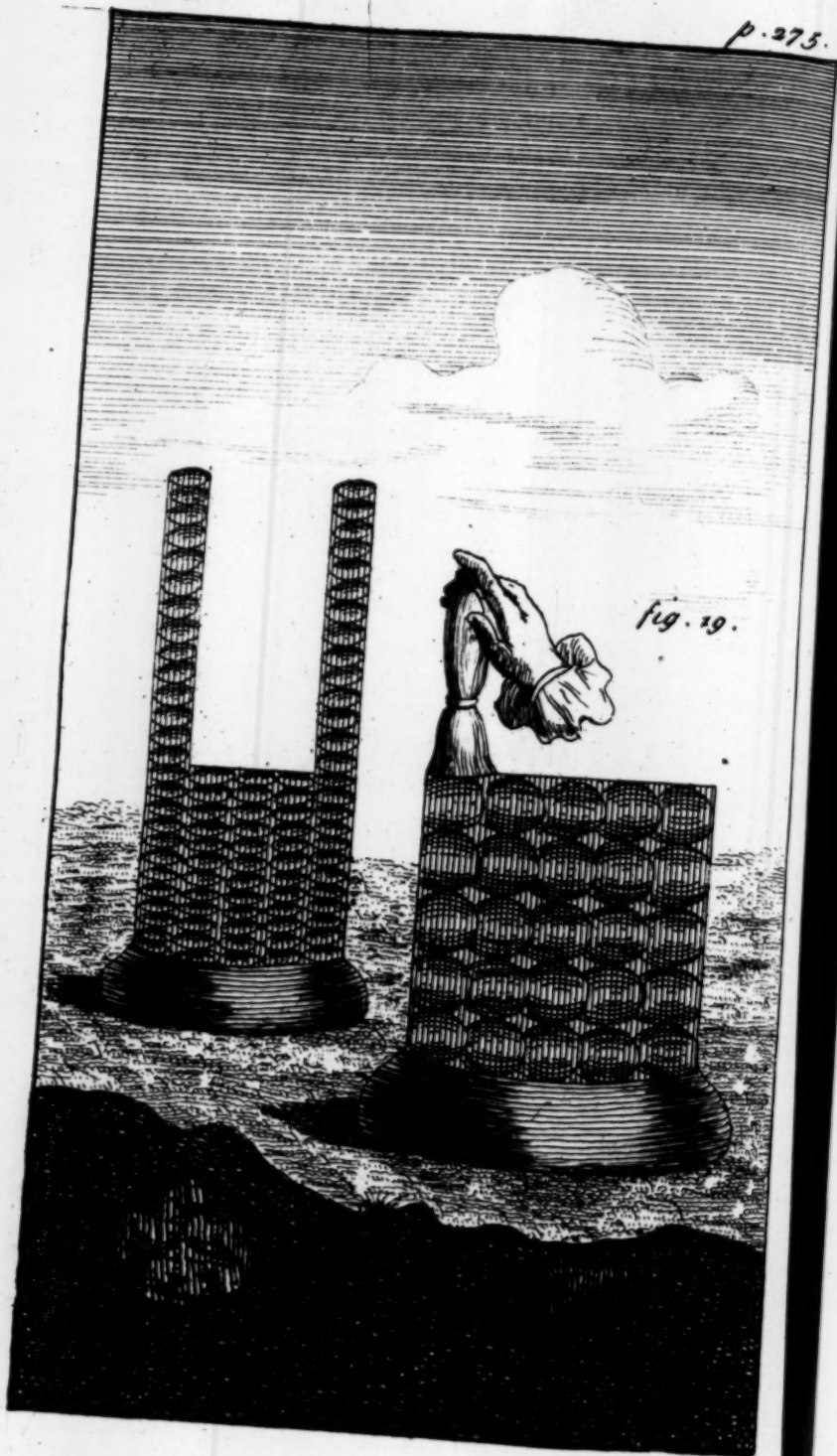


fig. 19.

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so many little Balls full of Air, and contracted by a foreign Force, incessantly endeavour to extend themselves, and by the Efficacy of their Spring thrust the adjacent Parts on all Sides, *Fig. 19.* Hence,

1. Pierce the right or left Side of a Cask, and the Wine will flow immediately. The Reason is not because its Confinement in the Cask is troublesome to it; it finds itself no better in Mens Bodies than in the Cask; the Cask preserves it, and Mens Bodies corrupt it. What is it then that determines it to flow? It is the universal Impression of its Parts; those Parts being impelled to the right and left, not only by their Motion of Liquidity, but also by the Spring of the internal Air, and by the Pressure which proceeds from the Gravity, and being always subject to follow the third Rule of Motion, are darted into the Air, because there they find less Opposition to their Direction.

2. Should a Dyke happen to be broke down, the Water of a River is turned aside, and leaves its Channel by the same Reason; the Water of a Pond which appeared immovable, is spread abroad in great Surges as of itself, overflows the Fields, and carries either Devastation or Fruitfulness round about.

3. Should a lively and clear Water, which springs out of the Brow of a little Hill, or from the Top of a Mountain, come by subterraneous Channels to embellish our Gardens; whenever it is at Liberty, you may see it spring

276 CONVERSATION XX.

up into the Air. The Action of Gravity made it at first descend from its Source; since its Parts being compressed by the Action itself of Gravity, and impelled a Thousand Ways, follow the Direction of Channels parallel to the Horizon, and where the Resistance is least, till at last finding a free Passage, but exactly in a perpendicular Direction, they lay hold on it by the same Principle: And as by the fourth Proposition they have a Force proportional to the Height of the Water which descends and presses them by its Gravity, they are rapidly darted into the Air; one would think they endeavoured to join their Source again; at least they want but little of reaching the Level.

Arist. But why does not Water rise as far as the Level itself of its Source?

Eud. 1. The Water loses of its Force in the Channels by Friction. 2. When it springs up, the Resistance of the Air divides its Parts; its Parts being divided, have thereby a larger Surface in Proportion to their Mass; having a larger Surface they meet with more Air in their Direction, and lose so much the more of their Force, the more they are obliged to divide it.

3. The Water which spouts up, falls back upon that which follows it, and weakens it by its Fall; and this hinders it from recovering the Level of its Source.

Would you be surprized now to see a Diver walk composedly to the Bottom of the Sea,

On the Gravity of liquid Bodies. 277

Sea, as we do here, in Order to seek Pearls, and to cast his Eye upon all that is round about him without feeling the Weight of the Water, even when he happens to be under a Vessel of a hundred Guns, and of a Crew of five Hundred or a Thousand Men†?

Arist.

† The Cause of this is excellently well explained by *Jo. Alph. Borellus de Motibus Natur. in Gravitate factis. Prop. 29, &c.* After he had shewn, that Sand in a very strong Vessel, cannot any Way be divided, and that a Wedge will by no Means enter into it; and also that Water in a Bladder, equally compressed on all Sides, can neither be streightened nor bent, nor at all moved: So likewise, says he, in the Body of an Animal, there is contained within the Skin, some Parts which are hard and solid, such as the Bones; others that are soft, such as the Tendons, Nerves, Membranes and Muscles; and others that are fluid, watry or oily. Now the Bones in an Animal cannot be broken or dis-jointed, unless the incumbent Weight presses one Way only, as it does on Porters: But if the Pressure diffuses itself all round, so as to press upwards and downwards, and sideways, with equal Force, so that there be no Part of the Skin but what is pressed, then it is impossible, that any Thing should be separated or put out of the Way. The same may be said of the Nerves and Muscles, which though they be soft, yet because they consist of tough and strong Fibres, they can all support one another, and resist an universally diffused spherical Compression; the same may also be said of the Blood and other Humours of an Animal, which are of a watry Nature; for as it is evident, that Water cannot be condensed, so likewise the Humours of an Animal, contained in the Cavities of its Vessels, though they may be bruised by an Impulse made from one or a few particular Places; yet they can never be forced out of their Vessels, or torn asunder by an universal Compression every Way. So long therefore as the solid, tendinous, or fleshy or liquid Parts, do not undergo any Separation, Contusion, nor are dis-jointed, nor their Situation at all changed; it is impossible, that any Pain or Uneasiness should follow in the Animal, which cannot arise from any other Cause, but separating that which was one continued Thing. Wherefore when Divers, &c.

And this is confirmed by what the famous Mr. Boyle observed, in his second Appendix to the Eleventh Hydrostatic Paradox, viz.

278 CONVERSATION XX.

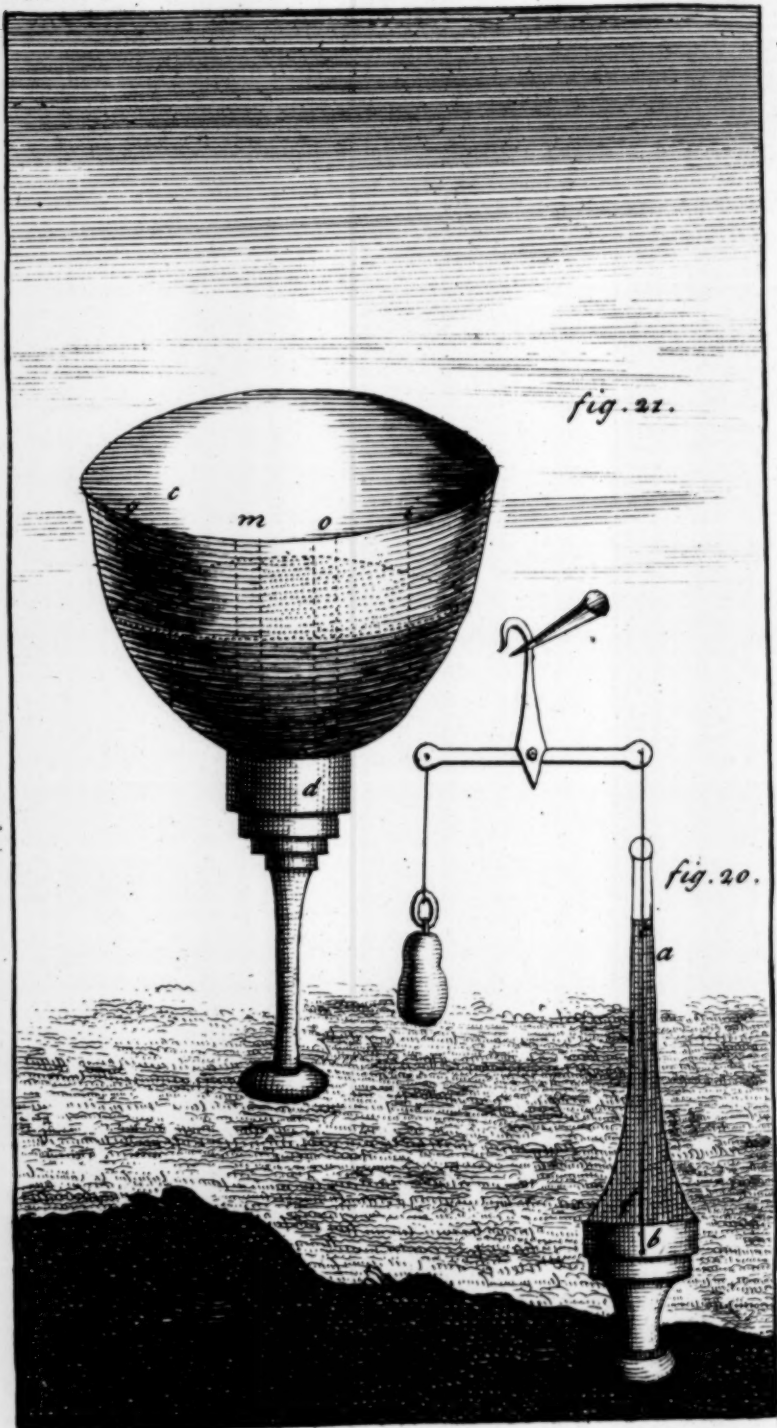
Arist. According to the Laws of the Union of the Soul and Body, we only feel Things in Proportion to the Changes which they produce in the Body, or in the Senses. Now the Water produces no Change, at least no considerable one, in the Body or Senses of the Diver. The Parts of the Water being thrust toward all imaginable Places, equally, or almost equally, push all the Parts of his Body toward a common Center; which Parts being disposed in Form of a Vault, and supported by the inter-

That a Tadpole, an Animal whose Flesh is very tender and soft, put into a Vessel half full of Water, so closed up, that the Air contained in it, being condensed eight Times as much as in its natural State, pressed upon the Water as much, as if a Column of Water of three hundred Feet in Height laid upon the Animal; moved itself notwithstanding, and swam about very quick, and found no Inconvenience that could be perceived.

However, because in most Animals there is a great deal of Air, which may easily be compressed and condensed; therefore, though no particular Member is disjointed, when an Animal is immersed very deep in Water, yet they must all of them necessarily be straightened and contracted, by the equal Weight and Pressure of the incumbent Water on all Sides, as Mr. Boyle says, happened to the Tadpole in the forementioned Experiment.

Besides, those Animals, whose Lungs are so formed as to contain a great deal of thin Air and Breath in them, though the other Parts of them be not at all hurt, yet their Breasts must of Necessity be straightened and contracted, in the same Manner, as the Cork is usually thrust into an empty Bottle, by the Weight of the Water, when it is sunk very deep. Therefore Men, whose Lungs are very large, when they dive very deep into the Sea, though they find no Manner of Inconvenience in any other Part of their Bodies, yet they labour under a Difficulty of Breathing, and a Pain in their Breast (though they have Air enough conveyed to them to breath). And thus the famous Mr. Boyle tells us of a certain Diver, that when he walked at the Bottom of the Sea, the Blood flew out at his Nose and Eyes. *Clarke's Re-bault*, Vol. I. p. 59.

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nal Air, sustain the equal, or almost equal Effect of the Parts of the Water, without being displaced or disordered in any sensible Manner. Therefore I ought not to be surprized that the Diver feels not the Weight of the Water. You have indeed deprived me of the Pleasure of a Surprize, by giving me one more agreeable.

Eud. You readily conceive my Meaning.

PROPOSITION VI.

“ A liquid Body weighs upon its Base according to its Height. The Impression of a liquid Body upon the Base that supports it, although its Parts act with an universal Motion, answers precisely to its Height and Base.

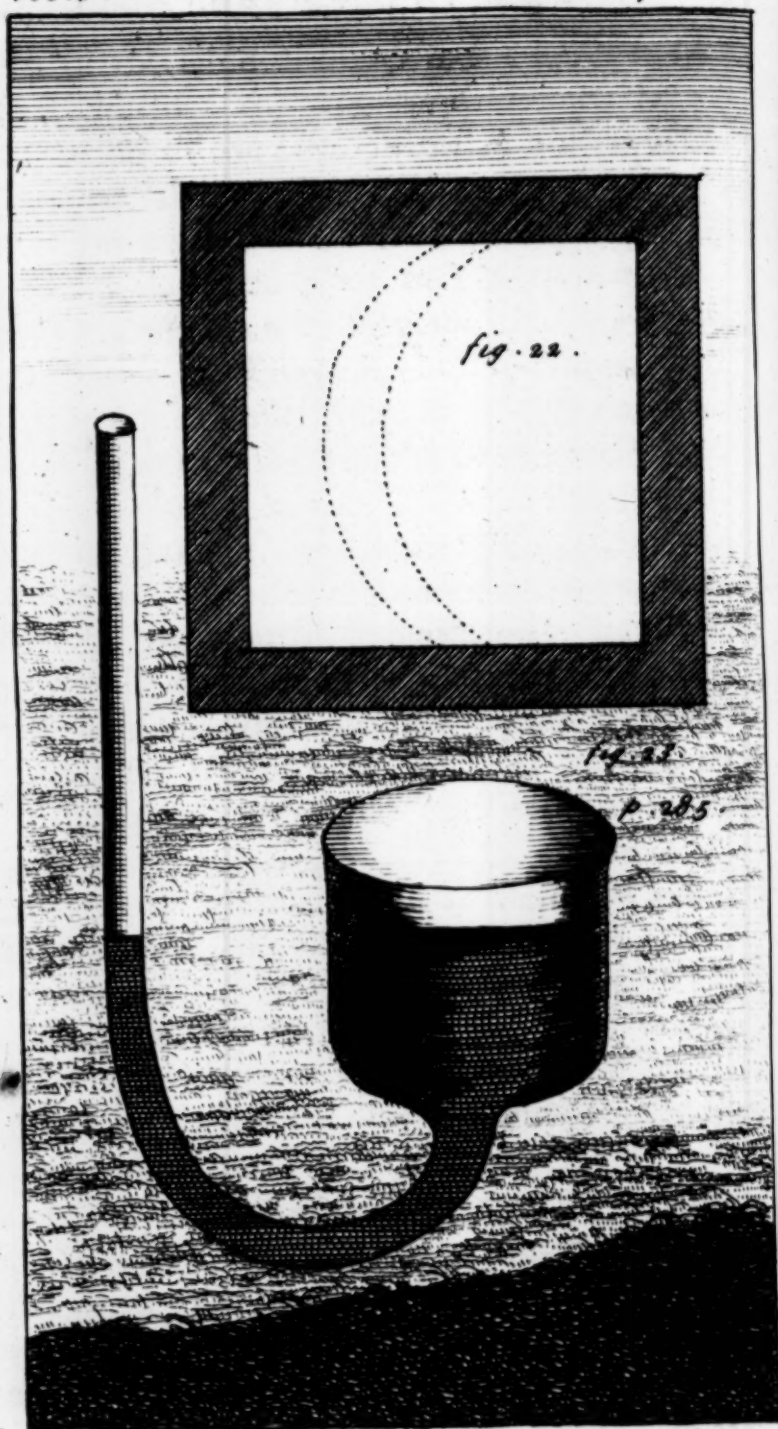
The Proposition is true, if when there is the same Species of Liquor, an equal Base and equal Height in the liquid Body, the Action of the Gravity upon the Base, is equal notwithstanding the Inequality of Size: But it is equal; it is, I say, equal if in a conic Vessel (*a*) *Fig.* 20. which only contains one Pound of Water, the Action of Gravity upon the Base (*b*) is as strong as in the wide Vessel (*c*) *Fig.* 21. which carries 100 Pound of Water, upon an equal Base (*d*), and under the same Height. It is demonstrated by Reason, that the Action of Gravity upon the Base is equally strong in those two Vessels; for the Parts, which immediately touch the Base of the conic Vessel, can-

280 CONVERSATION XX.

not be of the same Number and equally compressed, without the Action of Gravity be equal; being of the same Number and equally compressed, they ought to make the same Effort to get more Room, and consequently to press the Base alike. But 1. They are of the same Number, since by Supposition they cover equal Bases. 2. They are equally compressed; for in the conic Vessel there is at least one Column of Water of the Height of the wide Vessel; this Column has its Parts as much contracted as those of the larger Vessel, since the Pressure of a Column of Liquor answers to its Height by the fourth Proposition. Its Parts being equally compressed, make the same Pressure to pass into the Columns which surround it, since they act with an universal Motion by the fifth Proposition, and also with all their Forces, as all necessary Causes do. The Action of Gravity upon the Base is therefore equal in both Vessels.

In short, if the two equal Bases of two Vessels, equal in Height, but unequal in Width, are two moveable Pistons (*b, d*), Experience shews, that to support the Piston, which has in it only one Pound of Water in the conic Vessel, as much Force is required as to sustain the Piston which bears an hundred Pound in the other Vessel much larger. Therefore when there is the same Species of Liquor, an equal Base, and an equal Height of the liquid Body, the Action of Gravity upon the Base is equal;





On the Gravity of liquid Bodies. 281

equal; therefore the Impression of a liquid Body upon the Base which sustains it, though its Parts act every Way, answers precisely to the Height and the Base; which was to be proved.

But, you will say, in the Vessel which widens continually, the lateral Columns of Water (*gb, il*) ought to act upon those which are perpendicular to the Base (*mn, op*). It is true; but by the same Principle there is an equal Reaction on their Part: Hence the oblique Effort of the lateral Columns does not pass to the Base.

Arist. But when the Base of a conic Vessel is immovable, in supporting it I only find in the Water the Weight of one Pound. Let the same Base become moveable, and I find a Weight of an hundred Pound in the same Quantity of Water. What Charm changes at once the Weight of one Pound into the Weight of an Hundred?

Eud. In order to discover this secret Charm, I suppose a Bow (*a*) *Fig. 22.* whose absolute Weight is one Pound, and whose Spring is equal to the Weight of an Hundred. I bend this Bow and place it in a Machine between two Planes, joined in such a Manner, that it cannot separate them. After that I support the inferior Plane with the Hand, and I only find in the Bow the Weight of one Pound, I feel only the absolute Weight of the Bow. Why? While the bent Bow endeavours by the Force of its Spring to separate equally the two inseparable

282 CONVERSATION XX.

parable Planes, by the Effort which it makes against the upper Plane, it thrusts the lower Plane back as much toward the Sky, as it pushes it toward the Center of the Earth. For which Reason the Force of the Spring destroys itself in some Sort, with Respect to the Hand which sustains the Plane. Being thus destroyed it is not perceived, and spares me the Trouble of sustaining a Force of an hundred Pound Weight. But is the lower Plane suddenly detached? The Force of an hundred Pounds, which by Means of the Machine equally impelled it toward two opposite Points, now presses it only toward my Hand; and at once I have the Weight of an hundred Pounds to sustain.

Now the small Parts of Water in the conic Vessel are so many small bended Arcs, one Extremity whereof rests upon the Base, while the other is supported upon the inclined Sides of the Vessel. Is the Base attach'd to the Sides of the Vessel? The Spring of those small Arcs pushes the Base by the Effort which it makes immediately against it, and pushes it back by the Effort which it makes immediately against the inclined Sides of the Vessel. Being impelled and repelled equally at the same Time by the Force of the Spring, it does not make the Impression pass into the Hand which sustains it; and the Hand only feels the absolute Weight of the Liquor, or the Weight of one Pound. But is the Base detached suddenly from

On the Gravity of liquid Bodies. 283

from the Sides of the Vessel? The Force of the Spring protrudes it without any Repulse. Being impelled after this Manner by a Force of an hundred Pounds, it makes the whole Impression of it felt; and this is the Charm which at once changes a Weight of one Pound into a Weight of an Hundred.

Arist. Suppose that this Liquor of one Pound, suddenly changed into a Weight of an hundred Pounds, happens to freeze upon the moveable Base. What will happen?

Eud. The freezing will make one Pound Weight of an hundred Pound Weight; for the Force of the Springs, which proceeds from the universal Action of the Parts, will be suspended, since all the Parts will be fastened and linked together after such a Manner by the cold that they cannot flow, or be agitated or separated, or afford any Thing to the Mechanism of the Spring. Let Heat succeed the Cold: You will quickly find, as before, a Force of an hundred Pounds in a Weight of one Pound.

Arist. Can you find upon this Principle, and those which you have established, the Cause why a Stream of Water is sufficient to raise and burst the Bottom of a Cask loaded with a considerable Weight?

Eud. Yes, without doubt. Fill a great Hogthead with Water. Pierce the Hogthead being full and well closed. To the Hole which you have made, apply a Pipe of a certain

284 CONVERSATION XX.

tain Length, and as narrow as you please. A Stream of Water poured in through this Pipe, compresses all the Water which it encounters in the same Column, in Proportion to its Height, by the second Proposition: The Pressure of this Column passes to the neighbouring Columns; these communicate it successively to all the other, by the fifth Proposition. All the Water of the Cask is extraordinarily compressed. Being extraordinarily compressed, it makes extraordinary Efforts in order to get at Liberty, like a bended Bow; the Sides of the Cask seconded by the external Air, which weighs much less than Water, not being able to sustain those Efforts, the Efforts prevail, and the Cask bursts.

PROPOSITION VII.

- “ Liquid Bodies of the same Species, which
- “ have an immediate Communication with one
- “ another in some Part, act precisely against
- “ one another in the *Ratio* of their Height.
- “ By their being more or less large, their reciprocal
- “ Action is not more or less strong.

For those Bodies act against one another in Proportion to their being compressed, by the Proof of the fifth Proposition. Now, they are precisely compressed in the *Ratio* of their Height, by the sixth Proposition. Therefore they act against one another precisely in the *Ratio* of their Height, and a Stream of Water might

On the Gravity of liquid Bodies. 285

might elevate the whole Sea. Hence pour Water into communicating Tubes, *Fig. 23.* one of which is an hundred Times larger than the other. The Water places itself and remains upon a Level in both, provided the smaller one be not a Capillary Pipe or too small. For in a Pipe whose Diameter is a third of a Line, the Water ascends above the Level; because having a larger Surface in Regard of its Mass, and being better supported by the Inequalities, and the almost contiguous Sides of a Pipe so narrow, it acts less in Proportion to its Height against the Water of the great Tube, than the Water of the great Tube acts against it.

The Water of the capillary Pipe must be above the Level, that it may be in *Æquilibrium* with that of the great Tube. But this extraordinary Effect proceeds from the Smallness of the Pipe, and not from the capillary Column of the Liquor.

PROPOSITION VIII.

“ Finally, liquid Bodies, which flow, passing
“ from a larger Space into a straiter, accelerate
“ their Motion in the Passage.

For 1. In that Case the lateral Parts, which meet with some Impediment in the straitened Sides of the Channel; are more compressed by those which follow and incessantly overtake them; being more compressed they make the
greater

286 CONVERSATION XX.

greater Impression upon the Parts which flow directly and freely in the narrower Channel; and these finding a free Passage, make the less Resistance to those. 2. In this Situation, more Liquor must run in equal Times in a less Room, which cannot be done without the Velocity be accelerated. Thus the Water which flows under the Arches of a Bridge, runs more swiftly than it did before in a larger Channel. And the Liquor thrown out of a Syringe acquires in its Passage a Velocity of ten Degrees, if the Passage is ten Times straiter than the internal Part of the Cylinder; for a Piston ten Times larger than this Passage cannot advance an Inch in an Instant, but all the Liquor being decuple in Largeness, must advance an Inch in an Instant; all this Liquor thrust forward by the Piston cannot advance an Inch in an Instant, unless an Inch of Liquor decuple in Largeness, run out in an Instant by a Passage ten Times less; an Inch of Liquor ten Times larger cannot run out in an Instant by a Passage ten Times less, if the Liquor do not acquire a Velocity of ten Degrees in running out; since it is necessary that ten Parts, of the Length of an Inch, and as wide as the Passage, pass successively in an Instant; which cannot be done, unless they advance ten Times swifter than before: In a Word, every one has only the tenth Part of a divisible Instant, to pass through whole and intire.

Can

On the Gravity of liquid Bodies. 287

Can you find, *Aristus*, in those Truths which I have been speaking of, the physical Cause of a very singular Effect? You see this Tube stopped at one End, near the other is a moveable Key, which shuts and opens it at Pleasure; several communicating Tubes cut it at right Angles. I insert every one of those Tubes into the Orifice of a Hog's Bladder. Over the Bladders I put an horizontal Board, and over the Board a Weight of 1000 Pounds. A Child blows at several Times into the Pipe in the Middle; the Key being turned about, hinders the Air from issuing out, while the Child takes fresh Breath, the Bladders are inflated, and the Weight ascends. How does the Breath of a Child raise a Weight, which the most robust Man cannot move without a Machine?

Arist. A Stream of Water, which descends by a communicating Tube upon the Liquor which fills a Cask perpendicular to the Horizon, raises the superior End of the Cask, even when it is loaded with a considerable Weight; because the Excess of Compression, and consequently of the Spring, which the Stream of Water gives the inferior Column, is by it communicated to all the Columns, and the Excess of the Compression acts universally. After the same Manner the blowing of a Child lifts up an extraordinary Weight, because it gives the Air, which it directly encounters in the middle Pipe, an Excess of Compression and Elasticity, which is communicated universal-ly,

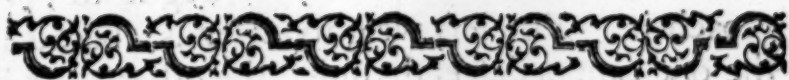
288 CONVERSATION XX.

ly, as in Liquors, and which consequently passes into all the Parts of the Air in the Bladders. In Proportion as the Child blows, the internal Air receives from a more agitated Air, which comes in, a new Excess of Pressure and Elasticity; and this Excess successive and united under the Weight by the Bladders, raises up the Weight more and more, and that so much the more effectually, as the Excess of Mass, which is found in the Weight, is less than the Excess of Velocity which is in the Child's blowing. Thus the blowing of a Child produces a prodigious Effect.

Eud. After this, *Aristus*, we may divert ourselves a little with the *Æquilibrium* of Liquors.



CONVER-



CONVERSATION XXI.

Upon Hydrostatics, or the Æquilibrium of Liquors ‡.

Eud. **D**O you explain the secret and reciprocal Action of liquid Bodies, and I will endeavour to explain that of liquid and solid Bodies. We shall have the Pleasure of seeing them counterbalance one another, overcome, yield, ascend, descend, and rest, being always more constant and faithful in observing certain Rules, than if they were endued with Reason.

Arist. Whenever liquid Bodies touch one another, the Compression which proceeds from the Gravity, and the Motions of Elasticity and Liquidity make them act universally against one another; and as they are not free, they act with all their Force in Order to surmount every Impediment. Are their Forces equal? None of them ascends, none of them descends, none of them prevails, none of them yields, by Reason of the Equality of opposite Forces. Are they unequal? The heaviest descends, be-

‡ See the Notes on the foregoing CONVERSAT.

290 CONVERSATION XXI.

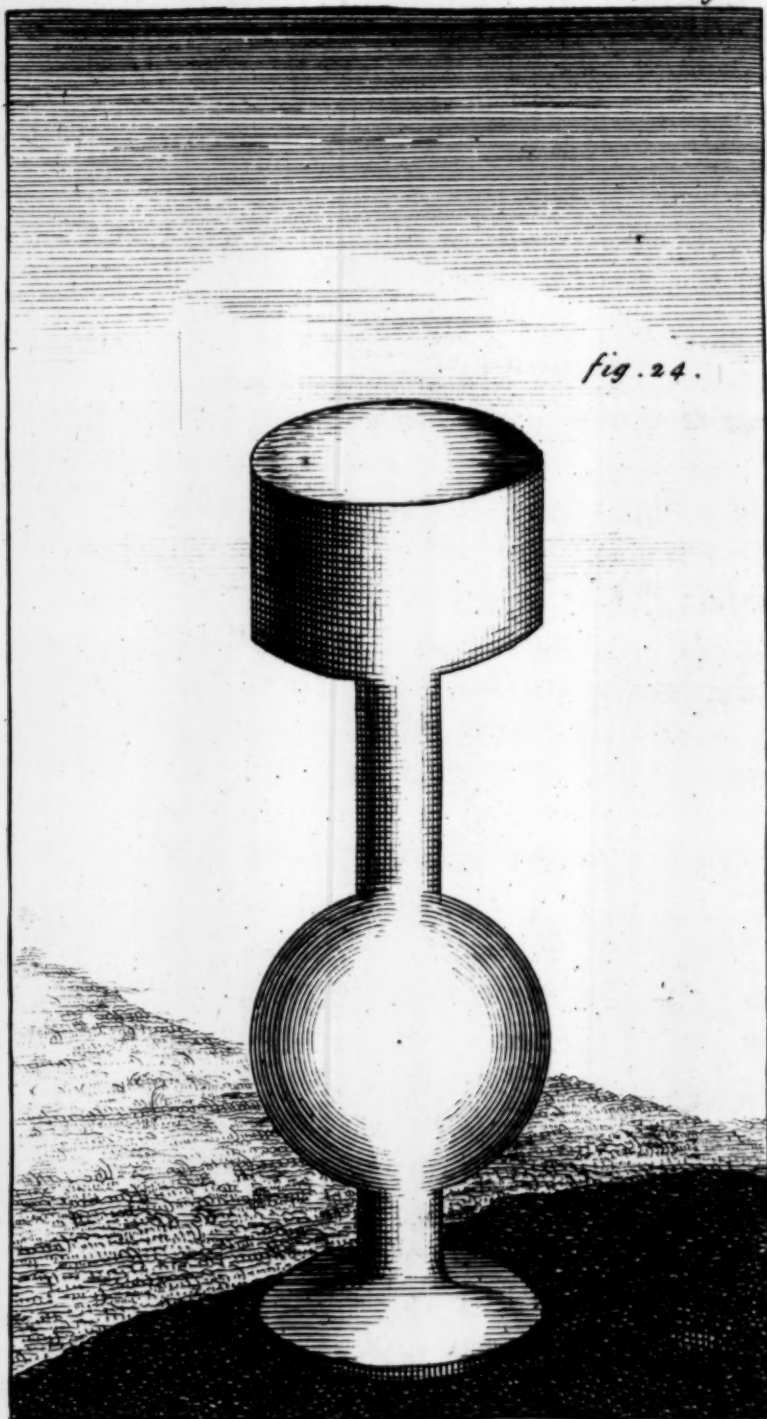
cause being protruded more strongly toward the Center of heavy Bodies, it ought to approach it. The less weighty ascends; because the one cannot descend, unless the other ascend in Order to make Room for it, and the less Force ought to yield to the greater.

Hence, 1. All the perpendicular Parts and Columns of liquid Bodies endeavour, as much as they can, to elevate one another, since they all act against one another, every Way, and with all their Force.

2. The less weighty Parts and Columns ought to ascend, having less Force to resist the Effort of the more weighty, which endeavour to elevate them. Accordingly they ascend. Sink into Water the End of a Syringe, and draw the Piston: The Water follows it, being thrust by the next Columns that are heavier and stronger.

3. You would say that Liquors of the same Species affect to be placed on a Level: Why? Because if any Part is above the Level, that below it being more compressed, and consequently heavier than the lateral Parts, which are not charged with the same Weight, descends and makes them ascend, till they are all in an *Æquilibrium* upon the Level, or in a Circle whereof all the Points are equally distant from the Center of heavy Bodies.

4. Liquid Bodies of a different Species, and of different Gravity, are not placed upon a Level; because the heavier ought to descend,
elevate



elevate and sustain the other. In Water we see Bubbles of Air ascend rapidly till they reach the Surface, the Reason is, because Air is much lighter than Water.

Eud. I take, *Fig. 24.* a small Glafs-Tube, [Passe-vin] which sustains a sort of Cup, and whose Base is a sort of Phial of the same Matter; I fill the Phial with red Wine. Then I fill the Cup and Tube with Water. You see a Stream, a Column of Wine, ascend calmly from the Phial into the Cup, while a Column of Water descends from the Cup into the Phial through the Tube, until the Wine have taken the Place of the Water, and the Water the Place of the Wine. What is it that determines those Liquors to change Place?

Arist. The Inequality of the Weight. The Column of Water is heavier, descends and elevates the Column of Wine.

Eud. But why is no Mixture made of those two Liquors in the Tube, as happens when I pour Water immediately upon Wine, or Wine upon Water in a Glafs?

Arist. The Water being turned over at first into the Cup, and descending upon the Wine through a very narrow Tube, descends gently, or else covering all the small Surface of the Wine almost at the same Time, it does not find Access into it, till after having lost much of its Velocity acquired in its Fall. Hence the two Columns of Wine and Water are quiet beside one

292 CONVERSATION XXI.

another: In this Situation their Parts, whose Agitation is very moderate, are much compressed, and have not Motion or Force enough to divide one another, to penetrate, to insinuate themselves, and to be intangled in one another's Interstices; and, in a Word, to be mixed with one another. But the Water which I pour upon Wine, or the Wine which I pour upon Water in a Glass, acquires in its Fall, being more free and upon a larger Surface, Motion and Force enough, to invade the Particles of Wine, disturb their *Æquilibrium*, diffuse itself into their Pores, or to receive them into its own, and be intangled with them without being able to disengage itself, after having lost much of its Force by Friction. And this is what causes the Mixture of Wine and Water in a Glass, although Water be more weighty.

In a Word, pour Water immediately into the Glass, put a light Slice of Bread upon the Water, and then let Wine flow gently upon the Bread: The Wine, which would be mixed, if poured on as they commonly pour it, diffuses itself upon the Water, without descending or being mixed. Why? Because in falling upon the Bread, and being filtered through its Pores, it loses much of the Force which it had acquired in its Fall; and, having at last no more than the Force of Gravity to mix and descend, it cannot make itself in the Water, being heavier, free Passages in Order to mix
with

with it, and deceive the Eyes rather than the Taste, by communicating its Colour to the Water. Here are some Traces of the mutual Action of liquid Bodies. What Rules do solid Bodies observe, which measure their Force immediately with liquid Bodies?

Eud. The Bulks being supposed equal, a solid Body weighs more, less, or equally ||?

Rule 1. Does it weigh more? It sinks wholly.

Rule 2. Does it weigh less? It swims uppermost.

Rule 3. Does it weigh equally? It swims and remains suspended in the Liquid.

1. Does it weigh more? It descends and sinks wholly. For being heavier, it ought to approach nearer to the Center of heavy Bodies. It cannot do that without elevating above it the lighter Bulk, which by its Weight and Liquidity ought to be diffused over it; Therefore it descends and sinks entirely.

How should it not sink after that Manner? Being more weighty, it is stronger; being stronger, it ought to elevate the Bulk that is

|| In all homogeneous and equal Bodies, the Densities are as the Weights; in unequal Bodies of the same Weight, the Densities are inversely as the Bulks; if therefore both the Weights and the Bulks differ, the *Ratio* of the Densities is compounded of the direct *Ratio* of the Weights, and the inverse *Ratio* of the Bulks; and therefore *dividing the Weights by the Bulks, you have the Densities*, that is, you will have Numbers that are to each other as those Densities.

The Weight of all Bodies may be compared by Means of the Balance; the Bulks are found by *immersing Bodies in the same Liquid; for the Weights which they lose, are as their Bulks. Vide Gravesande's Elem. Vol. I. p. 159, &c.*

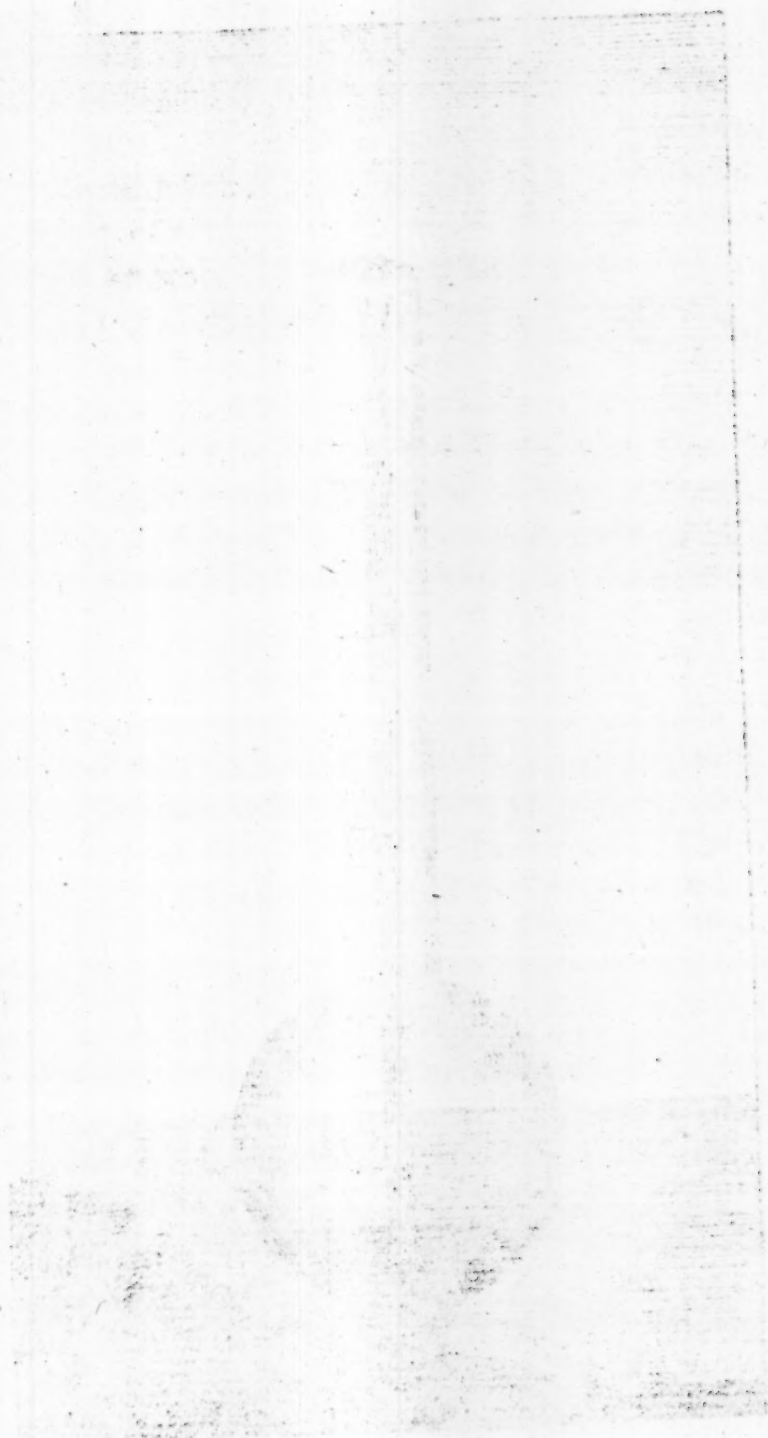
294 CONVERSATION XXI.

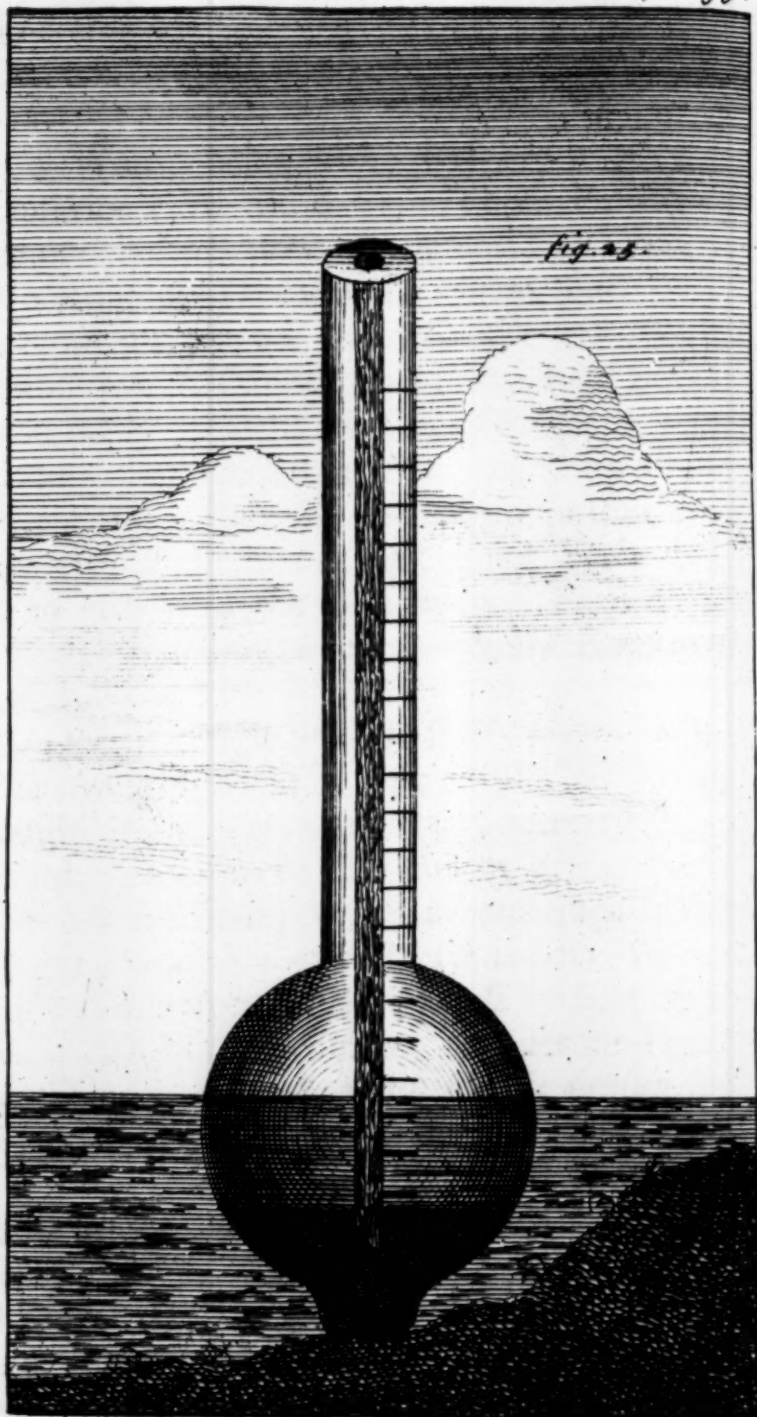
lighter, and consequently weaker. A superior Force, whenever it is necessary, is always victorious: Therefore, &c.

In a Word, being more weighty it presses the inferior Parts the more. Those Parts being more pressed, press the lateral Parts more. These being more compressed ascend, since they endeavour to extend themselves every Way, and find less Resistance above the solid Body, always ready to yield its Place to them. In ascending they have their Place filled up again by the Parts which the solid Body pushes immediately; these do not leave their Place but only to give it to the solid Body. Thus a solid Body that weighs more, wholly sinks and descends.

2. Does it weigh less? It floats above. Being less weighty, and by that Means less strong, it ought less to approach the Center of heavy Bodies, and to be elevated by giving Place to the heavier Bulk, which is consequently the stronger; the less Force always yields: Therefore it floats atop. Nevertheless in floating above it does not cease sinking to a certain Point, since being heavier than the Air, it presses the Surface of the Liquor more.

3. Does it weigh equally? It floats and remains suspended in the liquid Body. Being equally heavy, and thereby equally strong; whenever it is placed in the Bosom of the Liquid, it can neither descend nor ascend, since it can neither overcome nor yield. Equal Powers





ers are neither vanquished, nor victorious; therefore, &c.

Hence, 1. A solid Body which you sustain, weighs less with Respect to you, or loses of its relative Weight in Liquors, proportionally as they are more or less weighty.

They sustain it in Proportion to their Weight, and you have not that to sustain which they sustain. A solid Body which you sustain in Water, does it weigh ten Pounds in the Air? You only employ a Force of eight Pounds in order to support it, if an equal Bulk of Water weigh two Pounds; because it supports the Weight of two Pounds. Let us suppose two Pounds in *Æquilibrio* in a Balance. Let the Balance descend: If one of the two Pounds descend into the Water, it loses immediately of its Weight, with Respect to the other, in Proportion to the Weight of the Water: There is no more *Æquilibrium*, and the other outweighs. In short, Lead weighs less by a tenth Part in the *Seine*.

2. A solid Body, which swims, sinks proportionally as there is in the Liquor a greater or less Excess of Gravity. The Liquor-Balance or Areometer, *Fig. 25*. (it is a sort of small Glass Phial with a long Neck, sealed and closed hermetically; full of Air, and having a little Mercury in the Bottom). The Liquor-Balance, I say, is sunk more or less in different Liquors; more in Wine than in Water; and more in fresh Water, than in Salt Water.

296 CONVERSATION XXI.

Why? 1. The Liquor-Balance swims above, because it cannot descend and sink wholly, unless the Bulk compounded of Air, Mercury and Glass be wholly sunk; and this Bulk cannot be wholly sunk. The Mercury and Glass, each in particular, are heavier than the Liquor; but the whole Bulk, by Reason of the Excess of Levity which is in the Air that it contains, weighs less than an equal Bulk of Liquor. 2. The Liquor-Balance sinks more in Wine than in fresh Water, and in fresh Water than in Salt. You see the Reason of it; because Wine weighs less than fresh Water, and fresh Water less than Salt Water. The Salts, being more solid than pure Water, give a greater Gravity to the Salt Water.

Arist. Your Liquor-Balance makes me comprehend why such a Vessel, which sails safely upon the Sea from one End of the World to the other, would sink gently to the Bottom in the fresh Waters of a River or Lake. The Reason is, because the Salt Water of the Sea being much heavier than the fresh Waters of a Lake or River, can support a much greater Weight.

Eud. Nevertheless one may make the most solid Bodies, Stones, Brasses, and Gold itself, to float upon the fresh Water of a River. Make a Bridge of Stones as long as you please; let this Bridge have for Pillars only moveable Boats, which, without being able to move forward or backward, may descend or ascend, in Proportion

portion as the Water ascends or descends, like the Bridge of *Roban*; this Bridge of Stones, being loaded with Animals, Men, and Coaches, will not cease to float above; because the Bulk of Stones, Men, Coaches, Boats, and Air contained in the Boats, will be more light, by Reason of the Levity of the Air, than an equal Bulk of Water. By the same Reason, cover the Breadth of a River with Boats of Brass, or Gold, if you will; a whole Army may pass over, without the Brass or Gold ceasing to swim.

Arist. Your Opinion, *Eudoxus*, appears natural; but one Thing which occurs to my Mind, has a Tendency to destroy it. A Needle of Steel, placed gently and horizontally upon the Surface of Water, swims. I think it ought to sink intirely. It has neither the Form of a Boat, nor the Levity of the Air, to sustain it; and Steel is heavier than Water.

Eud. The Levity of the Air, and the Form of a Boat, with the Viscosity of the Surface of the Water, produce this Effect still. How is it produced? The Air is more easily attached to the Needle than the Water is, for the Needle is not easily wetted; the Water runs over it, without finding any Hold on it. This being granted; upon the viscous Surface of the water, whose Viscosity renders the Parts more difficult to separate, the Weight of the Needle with the Air which surrounds it, lays hold on it,

298 CONVERSATION XXI.

it, and continually envelops it, makes a sort of Cavity*, in which the Needle is contained as in a small Boat. The Bulk composed of the small viscous Boat, Needle and Air, is lighter than an equal Bulk of Water; though the Needle alone be heavier than an equal Bulk of this Liquor. The Needle ought therefore to swim much after the same Manner as a Boat of Brass, or as a Beam swims, because of the Air which it contains in its Pores.

Arist. In short, wet the Needle first: Thereby you detach from it a Quantity of Particles of Air, and fill up many insensible Pores of its Surface with Particles of Water; the Excess of Gravity sinks it, and makes it disappear to the Eye.

Eud. But the Wood, which at first swims above as the Needle of Steel, is at last wholly sunk. Whence does this Vicissitude of Gravity and Levity proceed?

* This is owing to *Repulsion*, of which we have farther Instances between Water and Oil, and generally between Water and all unctuous Bodies; between *Mercury* and Iron; as also between the Particles of any Dust.

If any greased Body, lighter than Water, is laid upon the Surface of Water, or Piece of Iron upon *Mercury*, the Surface of the Fluid will be depressed about the Bodies laid upon it. And where *Attraction* obtains, the Surface of the Liquor is higher about the floating Bodies, and does not run to a Level by its Gravity; but here where the repellent Force exerts its Action, Liquors, notwithstanding their Gravity, do not run down to fill up the Cavities which are made round the floating Bodies. See CONVERSAT. IX and XIV. Vol. I. and *Gravesande's Elem.* Vol. I. p. 15.

Arist.

Arist. With the Air which it contains at first it makes a lighter Bulk, and it swims. With the Water which penetrates it, and at length takes the Place of the Air which is forced to issue out, it makes an heavier Bulk, and sinks intirely. You are going to make me comprehend, no doubt, a Thing difficult to be conceived. Throw into cold Water a Ball of Wax, and it swims. Warm the Water, and the Ball sinks; increase the Heat, and the Ball ascends again.

Eud. 1. The Ball of Wax floats at first, because it weighs less than cold Water. 2. Afterward the Ball sinks, because it weighs more than an equal Bulk of Water rarefied by the Heat. 3. The Ball ascends again at last, because being at last rarefied itself by the Excess of Heat, which penetrates and dilates the Air that it contains, it becomes lighter than an equal Bulk of Water. You may find the Explication of a contrary Effect from the same Principles. A Carcass descends immediately in Water; after that it reascends, and then sinks again as of itself.

Arist. 1. The Carcass descends at first in the Water, because it is heavier. 2. It reascends, because the Fibres being relaxed for Want of Nourishment, or by the Action of the insensible Parts of the Water, the internal Air is set at Liberty, is extended, and enlarges the Bulk of the Body; and the Body having more Bulk, in Regard of its Mass, becomes at last lighter than

300 CONVERSATION XXI.

than an equal Volume of Water. 3. It sinks again, because the solid Parts from which the Air is gone forth, approach one another, and make the Body heavier and more compact.

Eud. But since there is more Weight in an human Body than in an equal Bulk of Water, how do those swim above who bathe themselves? How do they pass over Rivers by swimming?

Arif. 1. Being extended their whole Length upon the Surface of the Water, they cannot sink unless an equal Volume of Water open and give Place at once. But the Water opens and gives Way with so much the more Difficulty as a longer, larger and deeper Extension ought to open and give Place at once: For it must open and give Way with so much the more Celerity; and the Resistance of a Body answers to the Velocity necessary to move it. 2. The Air which they respire, being much lighter than Water, diminishes their relative Weight. 3. They compress the Water not only by their absolute Gravity, but likewise by the Motion of their Bodies; and the more they compress the Water, the greater Effort it makes to sustain them. In fine, by the Motion of the Arms and Feet they raise up the lateral Water; the adjacent Columns of Water are thereby longer; being longer they weigh more, since they all weigh in Proportion to their Height. This, I think according to your Principles, is the Reason why we keep on the Surface when
we

we bathe: Nevertheless I would not attempt to swim over the *Seine* upon the Force of this Reasoning.

Eud. Motion hinders from sinking, and makes the Diver ascend again from the Bottom of the Sea upon the Surface of the Water. Is he in an *Æquilibrium* at the Bottom of the Sea? Let him strike the Earth with his Foot, endeavouring to spring up to the Top. The perpendicular Motion which he acquires in this Effort diminishes his relative Gravity, and being seconded by the lateral Column, he raises himself above the Surface of the Water. All Motions diminish relative Gravity, excepting the direct Motion toward the Center of heavy Bodies: Hence you see Dregs and Sugar, when agitated, ascend in Liquor, and Dust rise up in the Air and darken the Sky.

Arist. You would make one believe that if a Philosopher, who had no Skill in swimming, and whom some Mischance should have precipitated into the Bottom of a River, had Presence of Mind enough to strike the Earth with his Foot, and spring up to the Surface, he might see the Bank; then being again precipitated by his own Weight, he might go along upon the Ground toward the Bank. Should he want to breathe, he might return and breathe above the Surface of the Water. When his Weight had again dragged him down to the Bottom, he might creep along as before, at last gain the Bank of the River, and escape
Danger

302 CONVERSATION XXI.

Danger by the Favour of his cool Blood and his Philosophy.

Eud. This he might do without being a great Philosopher. Some Time ago I saw a Man, who without knowing the *Æquilibrium* of Liquors, finding himself unhappily plunged into the Middle of a large and deep River, reached the Bank by creeping along under Water; while five or six Persons, whom a Shallop that was overset had thrown into the Water, were drowned in the same Place.

Arist. Water which suffocates us gives Life to Fish that are destined to yield us Nourishment. But how do Fish swim? How do they remain suspended and immovable? How do they ascend and descend with so much Liberty in the Water?

Eud. Fish have in their Bodies a sort of Bladder full of Air. In contracting it they contract the Body, and have more relative Gravity. By that Means at one Time they weigh as much as an equal Bulk of Water, and are immovable, or swim in the Water without descending or ascending: At other Times they weigh more and descend: Again, they weigh less and ascend. The Efforts which they make in turning and winding, by beating the Water as a Point of Suspension with the Tail, seconds their Vicissitudes of Gravity and Levity. I have made the Fish swim; do you make the Birds fly.

Arist.

Arist. It is easie to do that upon your Principles, after what has been said. Birds of themselves have more Gravity than an equal Volume of Air; the Partridge being mortally wounded by the Fowler's Shot, falls whenever she can fly no more. But this Excess of Gravity is compensated several Ways.

1. Birds which fly, dilate their Breast, extend their Wings, acquire a larger Bulk; and by that Means their relative Gravity is diminished.

2. Having a larger Bulk they divide the inferior Air with more Difficulty, because they must communicate to it a greater Velocity, and drive it farther in the same Time to divide it; and because it resists so much the more, the greater Velocity it requires in Order to its yielding.

3. The more they rapidly beat the inferior Air with their Wings, the greater Resistance they find from it; for it requires a greater Velocity to yield to the reiterated Strokes. The Air being beat with so brisk and quick a Stroke, that it has not Time to retreat, becomes a fixed Point for the Flight of Birds. By beating the Air with their Wings, as the Fish do the Water with the Tail, or the Diver the Earth with his Foot; they give themselves a Motion either to ascend or go forward. The inferior Air being compressed, seconds this Motion, as Water being pushed by the Oar behind the Shallop, seconds the Effort of the Rower; and as long as this Impression lasts,
you

304 CONVERSATION XXI.

you see Birds fly and hover in the Air, remain suspended, ascend and descend, much after the same Manner as Fish do in the Water.

Eud. When one understands the Flight of Birds, one may easily comprehend the floating Islands.

Arist. These are Tissues of Roots and Herbs mixed with a little Fuller's Earth; they are Masses composed of Fuller's Earth and Roots lighter than Water, which with the Earth and Air contained in them, form a Bulk lighter than an equal one of Water: This Excess of Lightness makes them float; and these are your floating Islands.

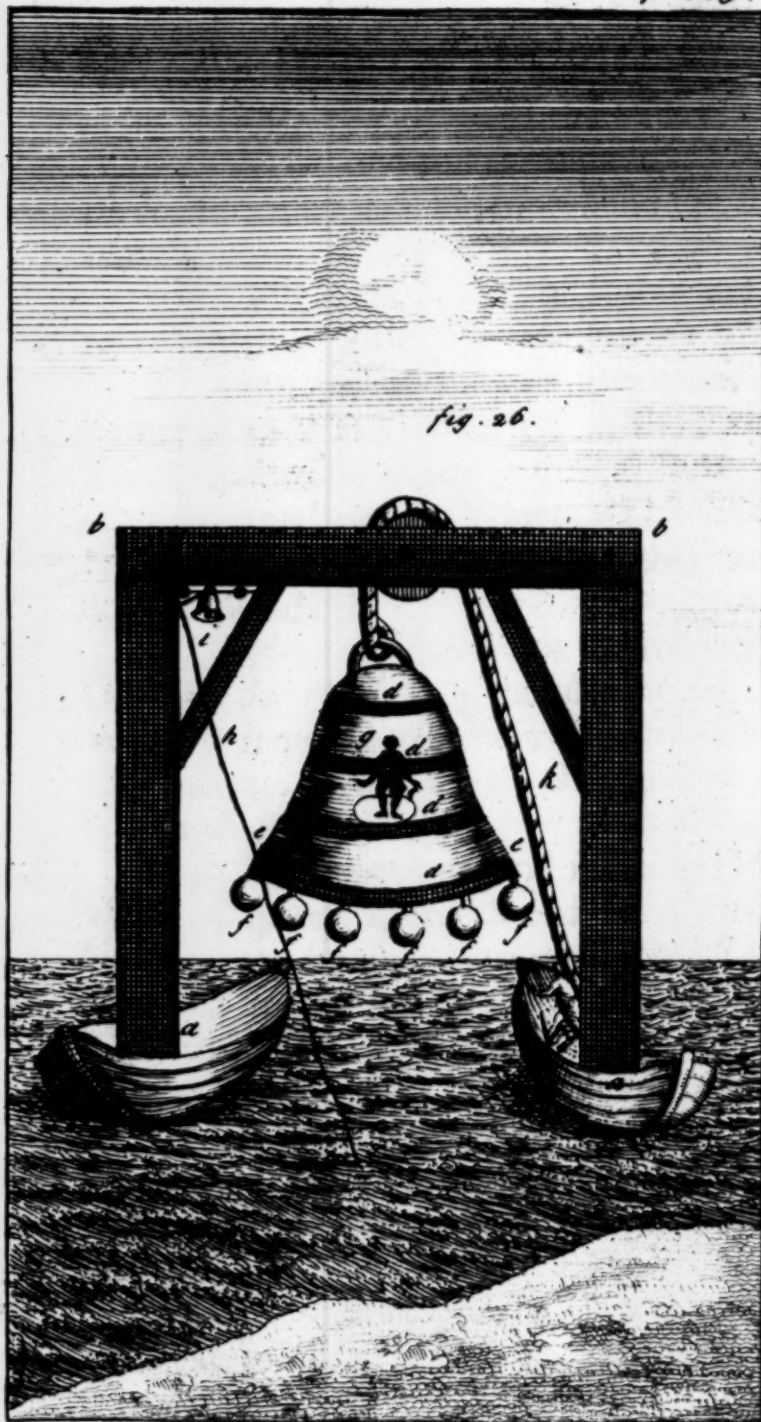
Eud. Before we finish this Conversation, let me have the Pleasure of perplexing you. Less Water is required to sustain a floating Island, or a Vessel in a narrow Place, than in one that is large and spacious.

Arist. In a very large and spacious Place the Water is spread more abroad, and rises to a less Height; but in a more contracted Place the Water is spread less abroad, and rises higher. Now the Water weighs, counterbalances and sustains the floating Island or Vessel precisely in Proportion to its Height (by your seventh Proposition of our last Conversation). Hence the narrower a Haven is, the less Depth is required in the Water.

Eud. But to conclude, what Method would you take to descend into the Bottom of the Sea
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in a great Volume of Air, and to carry Fire with you, without its being extinguished?

Arist. I would place my self upon a Plank in a Bell which should be made to descend perpendicularly into the Water, with the Mouth downward. The Bell, by Reason of its Figure, having the Parts supported by one another, would sustain the Weight of the Water; the internal Air, which would find no Vent to issue out at, would hinder the Water from entering very far by the Orifice, to wet me, and to extinguish the Fire.

Eud. It is a singular Contrivance, which has been luckily made Use of to bring up from the Sea some Millions of Pieces of Eight after a Shipwreck, *Fig. 26.* They suspended upon the Middle of a Cross-Tree (*bb*), which was supported upon two large Boats (*aa*), a Bell of Wood, from 13 to 14 Foot high, and nine Foot wide. It was encompassed with Iron Hoops (*dddd*); the Hoop at the Brim (*ee*) had several Iron Rings, to which were fastened as many Bullets (*ffffff*) to render the Bulk weightier than an equal Volume of Water, notwithstanding the Levity of the internal Air. A Man (*g*) was seated in the middle of the Bell. He held a small Cord (*b*) to ring a little Bell, when he had descended low enough, or was willing to ascend again. The little Bell (*i*) was fastened to the Cross-Tree. The Man being descended, gathered up the Piasters, and went from Time to Time to breathe

306 CONVERSATION XXI.

under the Bell. When the Air was heated too much, he rung the little Bell. Then by Means of a Cable (*k*), they drew him up again with the Bell and Piasters.

This Fact was learned from one who had been an Eye-Witness of it ^c.

You at first, *Aristus*, laid down what regards liquid Bodies in general; and when one comprehends the *Æquilibrium* of Liquors, one may easily discover the Properties of the Air. We have already discovered its Elasticity; let us endeavour to discover its Gravity; let us meditate upon these two Properties, each apart; then uniting our Lights we shall find an almost universal Agent in the Air, which is so little minded; and shall observe in its Gravity and Elasticity the Principles of a Thousand Effects, which are looked upon as so many Miracles in Nature.

^c Journ. des Scav. 1678. p. 137. 4 April.



CONVER-



CONVERSATION XXII.

Upon the Gravity of the Air, and its Effects.

Arist. **Y**OU will have it then, *Eudoxus*, that the Air weighs, however imperceptible and fine it be; and that we have the Weight of the Atmosphere to sustain, without our perceiving it*?

Eud. A Body, which affords some Hold to the Strokes of the subtile Matter which is the Cause of Gravity in Bodies, is ponderous. But the Air affords some Hold to the Strokes of the

* The *Air* is corporeal, heavy, its Parts yield to any Force impressed, and are very easily moved amongst one another; it presses in Proportion to its Height, and the Pressure every way is equal: It is plain therefore that it ought to be reckoned amongst Fluids.

Def. I. *All the Air which the Earth is encompassed with, considered together, is called the Atmosphere of the Earth, or simply, the Atmosphere.*

Def. II. *The Height of the Air above the Surface of the Earth is called the Height of the Atmosphere.*

That the Air is a Body appears from its excluding all other Bodies from the Place where it is.

That it yields to any Impression, and has its Parts easily moved, is not doubted by any one.

That it is heavy is proved by its pressing upon the Surfaces of other Fluids, and sustaining them in Tubes.

308 CONVERSATION XXII.

subtile Matter, since it is grosser, as we have observed in the Air Pump*: Therefore the Air ponderates.

In short, a Body which with another Body makes an heavier Volume, ponderates. Now the Air is a Body, which with another Body makes an heavier Volume; a Vessel full of Air has more Gravity than when it is empty of Air. *M. Homberg* pumped out the Air from a sort of Glass-Ball, whose Diameter was 13 Inches; and the Ball was lighter by an Ounce than before^d. Another Time, after having pumped out the Air from a Ball of 20 Inches Diameter, he found it at least two Ounces lighter^e. Therefore the Air is weighty.

Aristotle was sensible of this Truth, but made little Use of it, and it seemed to be eclipsed till the Time of *Toricellius*, who discovered and rendered it intelligible to *Father Mercenne*, a famous Monk. *Father Mercenne* imparted it to *M. Paschal*. *Guerick*, the famous Consul of *Magdebourg*, and *Boyle*, a learned *Englishman*, have demonstrated it by very curious Experiments.

Arist. It seems at first Sight, that if the Air ponderates, we ought to be overwhelmed under the Weight of the Atmosphere. But we see there is nothing to be feared on that Side. A Weight is not felt but when it causes some

* CONVERSAT. III.

^d Hist. de l'Acad. 1687. p. 260.

^e Hist. de l'Acad. 1696. p. 403.

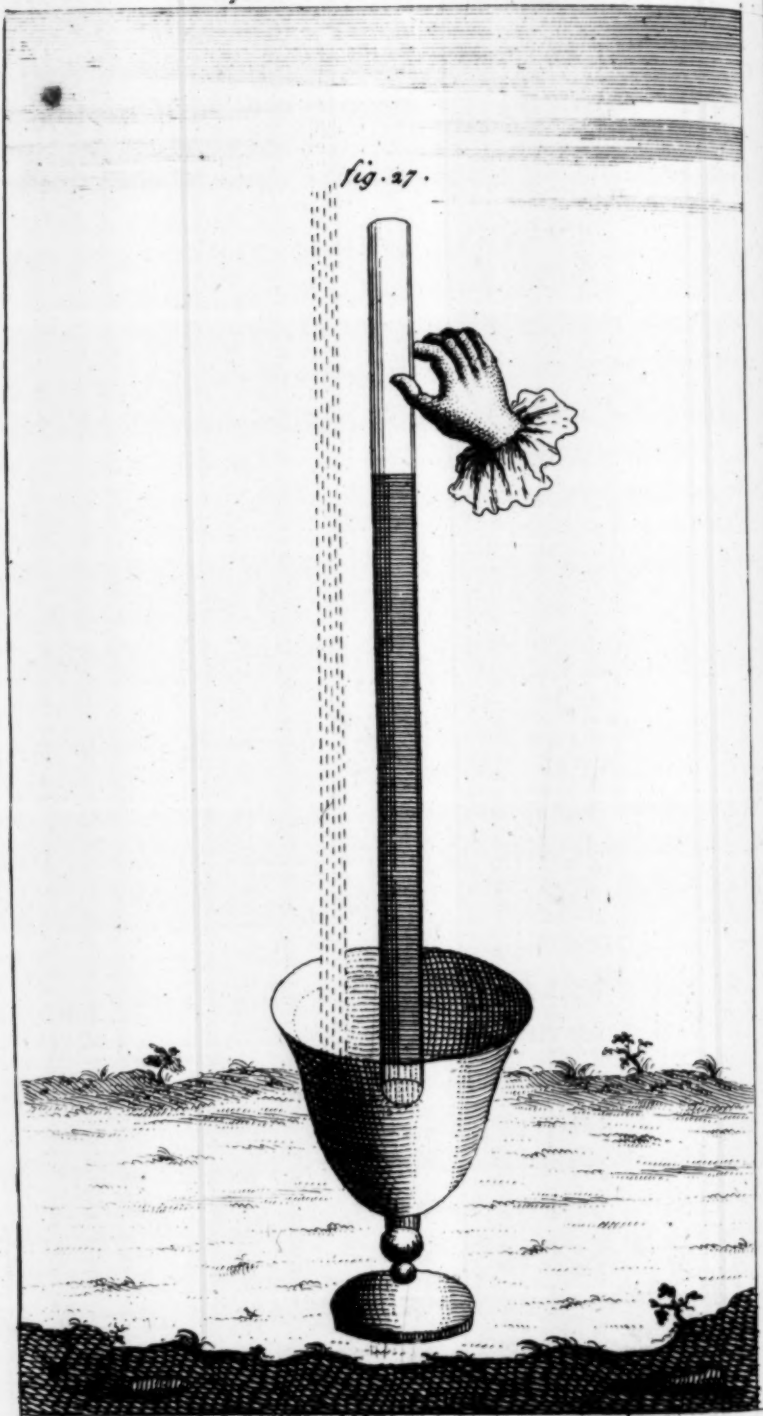
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p. 260.

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Change in the Organs of the Senses, as you have made me observe: The Weight of the Air causes no such Thing, since the Air encompasses the whole Body, and presses it equally on all Sides, both within and without.

Eud. Are you willing, *Aristus*, that I should present you with divers Facts which particularly respect the Gravity of the Air? You will explain them with your usual Penetration, and your Explication will give some Light to the Truth.

I pour Mercury into a Vessel; then I fill with Mercury this Glass-Tube of 36 Inches, closed up at one End with a Hog's Bladder. I stop the other End with my Finger, and plunge it into the Mercury in the Vessel; I remove my Finger: The Mercury of the Tube descends, and after some Ballancings, stops at 27 or 28 Inches, or thereabouts (*a*), *Fig. 27.*

Arist. I see at once the Reason of it upon your Principles. The Mercury descends at first, being impelled by the Gravity. While it descends, the accelerated Motion of its Fall makes it prevail over the Column of external Air, which counterballances it; it is carried below the Point of *Æquilibrium*. But the Column of Air being compressed, makes its spring to play; and prevailing in its Turn, it carries it back above the Point of *Æquilibrium*. These alternate Victories are repeated till the Excess of Force is lost: Hence the Ballancings or Vibrations, which precede the *Æquilibrium*.

310 CONVERSATION XXII.

Is the Excess of Force lost both on the one Side and the other? The Mercury is stoppt, because it is in a perfect *Æquilibrium* with the Column of Air, which counterballances it; and as the Air ought to be sometimes more, sometimes less weighty, in Proportion as it is more or less charged with Vapours, or more or less compressed by the Wind, the Point of *Æquilibrium* is sometimes higher, sometimes lower. Hence Mercury, always obedient to the Laws of *Æquilibrium*, rests without any capricious Humour, sometimes at 27, sometimes at 28 Inches, or thereabouts.

Eud. Make the Experiment in a lower Place, the Mercury descends less. Make it in an higher Place, the Mercury descends more. *M. du Perrier* made it near *Clermont* in *Auvergne*, at the Desire of *M. Paschal*. At the Foot of *Pierdome*^f the Mercury descended to 26 Inches three Lines and an half. Upon the Brow of the Hill, 150 Fathoms higher, to 25 Inches, toward the Top, 500 Fathoms higher, to 23 Inches two Lines g.

Arist. The lower the Place is, the higher is the Column of Air which sustains the Mercury; the higher it is, it ponderates the more, since Liquids ponderate, as you have made it appear^h, in Proportion to their Height; the more the Column of Air ponderates, the more

^f A Mountain near that Town.
de l'air, p. 196.

^g Mariote de la Nature
^h CONVERS. XX.

On the Gravity of the Air, &c. 311

it sustains the Mercury; the more it sustains it, the less it ought to descend, and the less it does descend. By a contrary Reason, the more elevated a Place is, the shorter is the Column of Air; the shorter it is, the less it ponderates; the less it ponderates, the less it supports the Mercury; the less it supports the Mercury, the more it ought to descend, and the more it does descend.

Eud. But in my Closet the Column of Air is shorter, by Reason of the Cieling, than those of the Palace of the *Sorbonne*, or the *Tuilleries*. Is the Mercury lower upon that Account? You see it almost at 28 Inches.

Arist. I have not forgot what you demonstratedⁱ, that in Liquids the Action of Gravity is diffused every Way. In a Vessel made in the Form of a Cane, a lateral Column, altho' it be shorter than that of the Middle, does not ponderate less upon the Bottom; because those of the Middle press it as much; as they are pressed themselves immediately by the Cause of Gravity. After the same Manner in your Closet, the Column of Air, altho' it be shorter than those without, ponderates no less upon the Mercury of the Vessel; because these press it as much as they are immediately pressed themselves by the Cause of Gravity. Now, when the same Force externally presses the Mercury in the Vessel, that of the Tube

312 CONVERSATION XXII.

ought to remain in the same Elevation, since it cannot descend without raising up the Mercury in the Vessel fixed by the same Force.

Eud. I suppose that the Air of my Closet has no Communication with the Air without. Ought the Mercury to descend?

Arist. The Mercury of the Tube cannot descend without elevating that of the Vessel; it cannot elevate it without compressing the Air of your Closet: It cannot compress it without ponderating more than the Air without; since the Air of your Closet retains the Pressure which it received from the Weight of the Atmosphere. But the Mercury in the Tube cannot ponderate more than the Air without; they are in *Æquilibrium*: Therefore the Mercury ought not to descend.

Eud. But if the small Column of Air contained in my Closet, ought to support this Mercury; why does My Hand, which holds the Tube, feel the Weight of the Mercury?

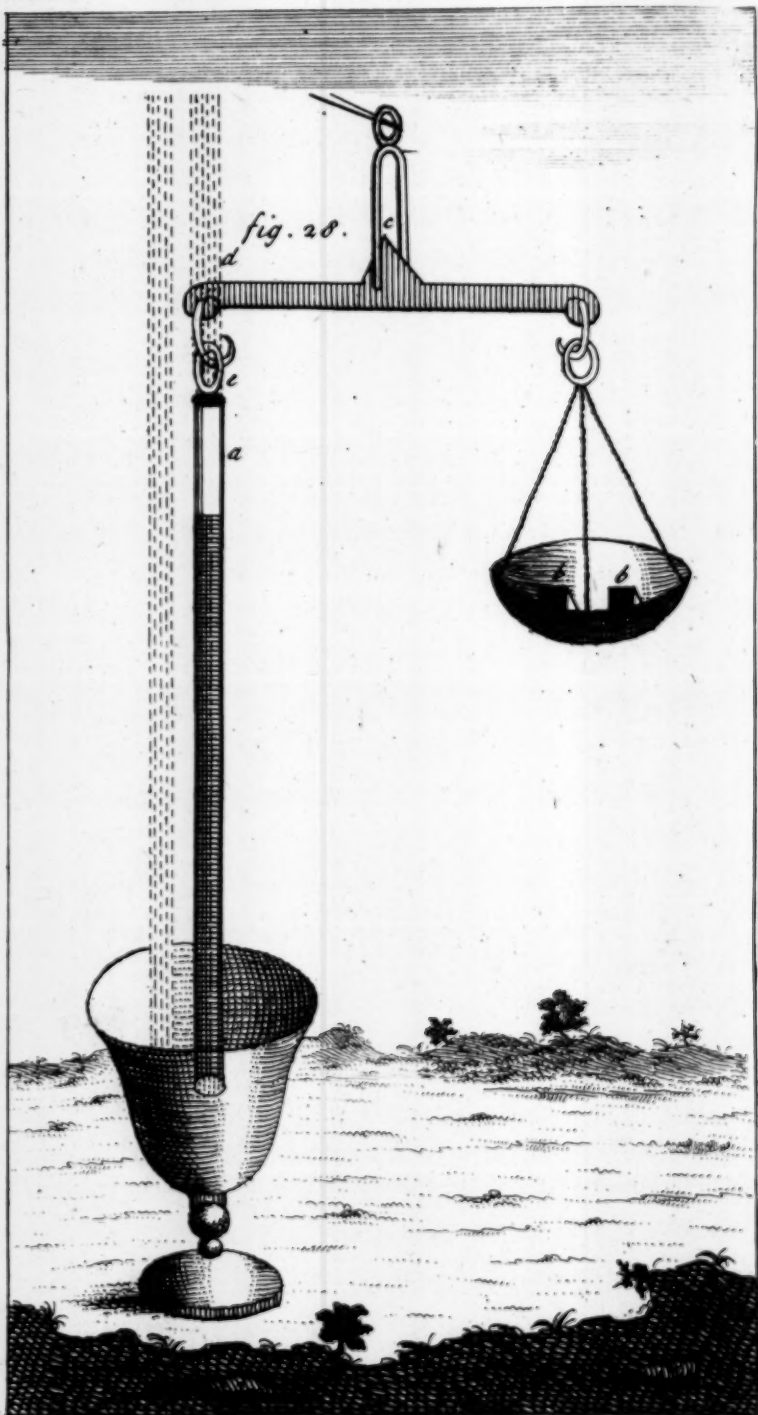
Arist. The Hand does not feel the Weight of the Mercury.

Eud. It feels an equal, or almost equal Weight.

Arist. This equal, or almost equal Weight is the Weight of the Column which descends upon the Tube perpendicularly, and which being no longer supported by the adjacent Column, employed in sustaining the Mercury of the Tube itself, ponderates upon the Tube with all its Force, and consequently makes the
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Hand, which sustains it, feel a Weight equal to the Weight of the internal Quicksilver, since it ponderates as much as the neighbouring Column, which is in *Æquilibrio* with the Mercury.

Eud. The Mercury, according to the Observation of *M. Amontons*, remains sometimes unequally suspended in equal Tubes; in Tubes of different Glafs, and much lower in an Iron Tube ^k.

Arist. The Inequality of the Pores must give Access to some Matter more or less subtile, and unequally ponderous into the Tubes.

Eud. However that be, without having any other Interest in View but that of Truth itself, let us go about to weigh the Air. Let us weigh the Column which descends upon this Tube, *Fig. 28*. I take off one of the Scales of the Balance. Upon the Beam, from which I have loosed it, I suspend the Tube (*a*), which always contains the same Quantity of Mercury. In the other Scale, whose Weight equals that of the Tube alone, I put the Weight (*b*) of one Pound. That is the Weight of the Mercury contained in the Tube. I sustain the Balance by the Middle (*c*). Every Thing remains in a perfect *Æquilibrium*; the Weight of one Pound does not elevate the Tube, which can be retained only by the Weight of the Column of Air (*d*), which descends upon the

^k Mem. de l'Acad. 1705. Trev. 1712. p. 1408.

314 CONVERSATION XXII.

upper End of the Tube. How much does it weigh?

Arist. It weighs one Pound. For it weighs as much, as the Column which falls upon the Mercury of the Vessel: There is no other Difference but the Height of the Tube. Now the Column, which falls upon the Mercury of the Vessel, weighs one Pound, since it sustains one Pound of Mercury in the Tube: Therefore the superior Column weighs one Pound. In short, it hinders a Pound Weight, which is on the other Side in the Scale of the Balance, from preponderating.

Eud. I bore the Bladder (*e*), which closes up the Tube, with a Pin. I draw back the Pin. There is no more Mercury in the Tube; it is all sunk into the inferior Vessel already.

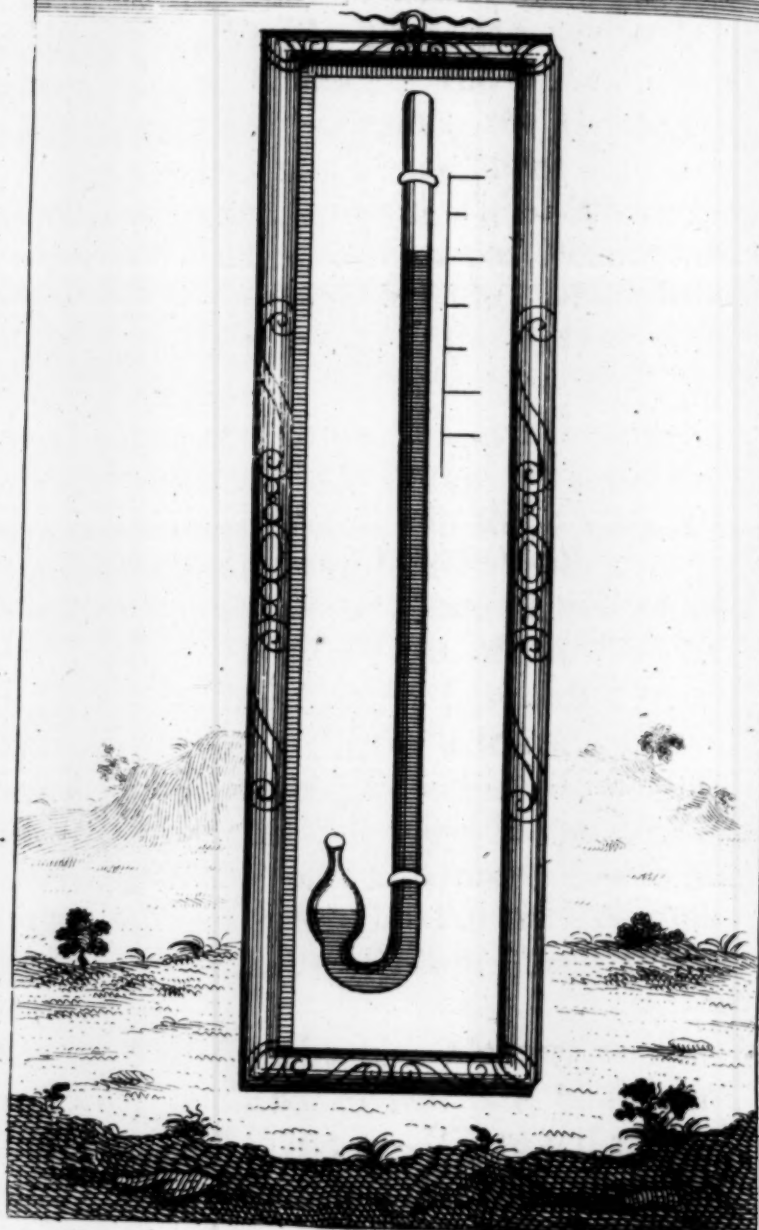
Arist. A Column of Air of one Pound, which enters through the little Hole of the Bladder, with one Pound of Mercury, has made a greater Weight than that of the external Column, which sustained the one Pound of Mercury by descending upon the Mercury in the Vessel. The greater Force ought to prevail, raise up the weaker, and descend. All the Mercury has observed the Laws of Nature; and here it is in the Vessel.

Eud. Let us fill with this Mercury another Glass-Tube, one End of which is closed up without Vent. I invert it. There is the Mercury suspended as in the first. I lift up the lower End as far as the Surface of the Mercury,

179



fig. 29.



ry, which floats in the Vessel; a Drop of it falls from the Tube. You see the rest spring up rapidly as far as the upper End, which is sometimes broke by so sudden a Motion.

Arist. Whenever a Drop of Mercury comes out of the Tube, the *Æquilibrium* ceases. The Air, becoming victorious all at once, gives a sudden Impression to the rest of the Mercury, which makes it ascend hastily. Thus, when two Weights are in *Æquilibrium* in a Balance, take something away quickly from the one Weight; the other will presently outweigh, and rapidly elevate the diminished Weight.

Eud. This Tube, which they commonly call the *Toricellian* Tube, because *Toricellius* first invented it, is a true Barometer, when it contains Mercury; since it serves to measure the Gravity of the Air. Let an Enameller bend it at the lower End, and join a small Phial to it, which affords Access to the external Air: then hang it up perpendicularly upon a Board marked with Degrees, to the Height of between 27 and 28 Inches, or thereabouts, from the Level of the Mercury in the Phial, *Fig. 29.* It is a single Barometer which informs you of fair Weather, Rain, Winds, Storms, Calm, or Tempest, and discovers to you beforehand the Danger or Safety, the Pleasure or Toil of a Voyage or Walk. By what secret Charm does a Tube, filled with Quick-silver, discover Futurity?

Arist.

316 CONVERSATION XXII.

Arist. I acknowledge I do not well comprehend this secret Charm, and the Prognostics of the Barometer are more certain, as I think, than the Cause which produces them.

Eud. The Mercury of the Barometer ascends or descends, in Proportion as the Air is more or less ponderous. The Air weighs less in rainy Weather, and more in fair Weather; and consequently it begins to weigh more, when the Weather becomes fair. For which Reason the Mercury is lower in rainy Weather, and higher in fair Weather. Hence, if the Mercury descend, it is a Sign of Rain; if it ascend, it is a Sign of fine Weather. Here is the Charm which makes us foresee fine Weather or Rain, Calm or Tempest.

Arist. This secret Charm still leaves some Uneasiness in my Mind. In fair Weather, the Air appears less charged with Vapours or Particles of Water. How then does it weigh more?

Eud. Then the Air appears less charged with Vapours; because the Vapors being more attenuated by the Rays of the Sun, or by the Heat of the Earth, being more subtile, and diffused in the great Circles of the Atmosphere, do less interrupt the Rays of Light. Nevertheless it is more charged; for then the Rivers and Fountains diminish, the Earth is dryer, and the Plants, Flowers and Fruits wither. Where are the Vapors, if not in the Atmosphere?

Arist.

Arist. What, when dull and gloomy Clouds veil the Heavens from my Eyes, does the Atmosphere contain fewer Vapours, than when the Heaven is clear, serene, and smiling? Pray, what is it then that forms those obscure Clouds?

Eud. They are Vapours that descend from the more elevated and larger Circles, and which being more united in the lower and smaller Circles, obstruct the Passage of the Light.

Arist. But ought not the Descent of Vapours to press and weigh down the Air, and consequently make the Mercury to ascend?

Eud. 1. The Descent of the insensible Vapours, which precedes the Rain, discharges the Air imperceptibly; hence the Mercury descends, and prognosticates Rain.

2. The Descent of the Vapours, united into sensible Drops, makes the lateral Air to ascend, whether it be by their Weight when they fall, or by the Efficacy of their Spring and Reflection at the End of their Fall. In short, fasten two Bodies of different specific Gravity to the two Ends of a Thread, a Bullet of Lead for Example; and a Ball of Cork; so that those two Bodies may swim in a long Tube full of Liquor. Fasten the Tube perpendicularly to one of the *Radii* of a Ballance, and fasten an equal Weight to the other. Let this Weight and the Tube be in *Æquilibrium*. Cut the Thread which fastens the Lead and Cork together; the Cork ascends, and the Lead descends;

318 CONVERSATION XXII.

scends; the *Æquilibrium* is lost; the Tube is elevated¹. Why? Because the Parts of the Liquor weigh less, when they are raised up by the Weight which descends. After the same Manner the Air being raised up by the Vapors which fall, ought to be lighter; being lighter, it permits the Mercury to fall. Thus the Mercury being sunk, foretells the Fall of Vapors and Rain.

They affirm, 'tis true, that in the torrid Zone, which is between the Tropics, the Mercury ascends continually in the Night, instead of descending; altho' the Vapors arise in the Day Time, and fall down again at Night. But in those Regions, 1. The excessive Heat dilates the Air in an extraordinary Manner in the Day Time, and consequently renders it lighter. 2. The Fermentations, caused by the Violence of Heat in the Surface of the Earth and Water, elevate the Air in the Day Time. 3. The Vapours and Exhalations that spring up on high, by the Force of these Fermentations, have less relative Gravity, than when they are in *Æquilibrium*; and compose, if I may say so, the same liquid Mass with the Air.

Sometimes in this Countrey, a Wind being reflected, which blows from below upward, bears up the Air, renders it lighter, and produces on the Barometer the same Effect as Rain.

Hist. de l'Acad. 1711. p. 5.

Finally,

On the Gravity of the Air, &c. 319

Finally, upon the inferior Mercury of the Barometer I pour 14 Inches of Water; the Mercury ascends one Inch in the Tube.

Arist. Because an Inch of Mercury is in *Æquilibrium* with 14 Inches of Water.

Eud. Put into this Water the End of a Syringe, draw the Piston, and the Water follows it.

Arist. Is it astonishing that the external Air, which weighs 28 Inches of Mercury, or thereabouts, makes the Water to ascend, when by lifting up the Piston you remove all Obstacle to the rising of the Water?

Eud. Is it the Air then, which also makes Water ascend to about 32 Foot in attracting Pumps, when the lower End of the Barrel is in the Water, and one draws the Piston?

Arist. The Air, which sustains and elevates the Mercury to 28 Inches in the Barometer, sustains and elevates the Water to 32 Foot, or thereabouts, in the attracting Pumps, if the Weight of 28 Inches of Mercury, and the Weight of 32 Foot of Water, are nearly equal: But they are nearly equal; since one Inch of Mercury, as we have said, equiponderates with 14 Inches of Water: Therefore the Air sustains and elevates Water to 32 Feet, or thereabouts, in attracting Pumps.

Eud. In the mean Time the more Water ascends in the attracting Pump, the greater Resistance we find made against the Force which lifts up the Piston.

Arist.

320 CONVERSATION XXII.

Arist. The more Water ascends, the more does the Column of Air which bears it up employ of its Force to support it; the more of its Force it employs for this Use, the less it has to counterballance the perpendicular Column, which falls upon the Piston. The less that counterballances this, the more this preserves of its Weight for opposing itself to the Elevation of the Piston. Hence the more Water ascends, the greater Resistance one feels.

Eud. The Resistance then which one feels, is not properly the Resistance of the Water.

Arist. It is properly the Resistance of the superior Air.

Eud. The Resistance ought to be felt then upon the Surface of the Hand, which draws the Piston, and which is under the Column of Air.

Arist. That ought not to be, if the Surface of the Hand is equally pressed contrary Ways by the external and internal Air; for according to the Laws of the Union of Soul and Body, the Soul does not feel but when some Change happens in the Body. Now the Surface of the Hand is equally pressed contrary Ways, both by the internal and external Air; 'since the first pushes back by its Elasticity, as much as the other pushes by its Weight: Therefore the Resistance ought not to be felt upon the Hand which draws the Piston.

Eud. It ought to make itself be felt when it is.

Arist. When it there causes any Change in the Organs, I grant it.

Eud. But to conclude, why is it felt in the Piston?

Arist. It ought to be felt in the Piston, if the Column which descends upon the Piston employs more Force to thrust it downward, than the lateral Column employs to thrust it upward again; the Hand, which draws the Piston a contrary Way, ought to feel this Excess of Force. But the Column which descends upon the Piston, employs more Force to thrust it downward; since in Order to thrust it downward, it employs the Force which the lateral Column employs to bear up at once both the Water and the Piston. Therefore, &c.

The Resistance ought to be felt where the free Force of the Weight of the perpendicular Column is united. But it is united in the Piston; for it is united in the Base, and this Base is the Surface of the Piston.

Eud. Here is, I think, one Fact sufficiently cleared up. Let us now observe some Marks of the Air's Gravity in the Air-Pump, *Fig. 1.* I fit to the Hole of the Copper-Plate the Orifice of a flat Bottle, cased with Straw. At once pumping out the Air my Bottle is broke.

Arist. According to the Rules of Natural Philosophy, the Bottle ought to break and fall into Shivers, as it does, if the two opposite Sides, which are, as it were, two opposite Planes, ought to approach one another: Now

322 CONVERSATION XXII.

they ought to do it. For they cannot be impelled toward one another by two Columns of Air, whose Diameter is equal to their Diameters, without advancing toward one another, unless they be supported by an internal Force, equal to the Force which impels them. They are not supported after that Manner, since the Air is pumped out. Therefore, &c.

Eud. I pump the Air out of the Receiver. The Receiver is not broke to Pieces.

Arist. Its Parts being disposed in Form of a Vault, and sustained by one another, are Proof against the Gravity of the external Air.

Eud. In vain do I try to separate the Receiver perpendicularly from the Machine.

Arist. The Action of the Gravity of the Air, diffused universally, retains them united.

Eud. Therefore it is the Action likewise of the Air's Gravity, which hinders my separating perpendicularly these two polished Marbles.

Arist. No doubt of it.

Eud. In short, I suspend them in the Receiver. — I pump the Air out at several Times. — The inferior Marble is separated as of itself. That is because it is no more sustained by the Pressure of the Air. Nevertheless I separate them horizontally out of the Receiver, without any Obstacle from the Pressure of the Air.

Arist. When you endeavour to make them run, or slide upon one another, the Air behind them

them seconds your Effort, as much as the Air before them resists it. Hence there is little Opposition to the horizontal Separation; but there is no Air between the two Marbles to second their perpendicular Separation. You have the Pressure of the Air, which unites them, to overcome without any Help.

Eud. These Hemispheres void of Air, so famous, and which could scarcely be separated by Horses, would no longer astonish you.

Arist. No more than the two polished Marbles. The Union both of the one and other, proceeds equally from the Weight and Pressure of the external Air.

Eud. But are the two Columns then so very weighty, which answer to the two Hemispheres?

Arist. Let us suppose that the Diameter of each Hemisphere is a Foot; the Column of Air, which answers to each Hemisphere, weighs more than 2160 Pounds. It weighs more than a Column of 30 cubical Foot of Water, since it can support 32. Now a Column of 30 cubical Foot of Water weighs 2160 Pounds; for a cubical Foot of Water weighs 72 Pounds; and 72 Pounds, multiplied by 30, give 2160 Pounds. Therefore the Column of Air, which answers to each Hemisphere, weighs more than 2160 Pounds. What will it be, if you double the Diameter of each Hemisphere?

324 CONVERSATION XXII.

Eud. Thus, I think, we have Facts enough to prove the Gravity of the Air, and that we incessantly bear a Weight of more than 1000 Pounds, without perceiving it. Let us see some Facts which particularly respect the Spring of the Air. But what do I hear? They are coming to interrupt us. To Morrow, *Aristus*, I shall expect you. I wish you would be here by five in the Morning, so much Pleasure do I find in your Conversation.



CONVER-



CONVERSATION XXIII.

Upon the Effects of the Spring of the Air †.

I Was waiting for you, dear *Aristus*, in making Tryal of an excellent Air-Pump. — The Piston descends at first without any Obstacle.

Arist.

† It has been shewn, that the Air has the Properties of other Liquids; but besides it has another Property, which is, that it can take up a greater or lesser Space, according as it is compressed with different Force; and as soon as that Force is diminished, it expands itself. By Reason of the Analogy of this Effect with the Elasticity of Bodies, this Property of the Air is called its *Elasticity*.

The Elasticity of the Air is as its Density; for this last is inversely as the Space taken up by the Air, and therefore as the Force compressing the Air, which is equal to that by which the Air endeavours to expand itself, but this Force is its Elasticity. *S. Gravesande's Elem. Phys.* The Air is loaded by the Weight of the whole Atmosphere pressing every Way, according to the Nature of a Liquid; the Force it exerts does no Way depend upon its Elasticity; because whether you suppose Elasticity or not, that Force which arises from the Weight of the Atmosphere, and is equal to it, can no Way be changed: but as the Air is elastic, it is reduced to such a Space by the Weight of the Atmosphere, as that the Elasticity, which reacts against the compressing Weight, is equal to that Weight. But the Elasticity encreases and diminishes as the Distance of the Particles diminishes or increases, and it is no Matter whether the Air be retained in a certain Space, by the Weight of the Atmosphere, or any other Way. For in either Case it will endeavour to expand it self with the same Force, and press every Way. Therefore if the Air near the Earth be included in any Vessel, without altering its Density, the Pressure of the included Air will be equal to the Weight of the

326 CONVERSATION XXIII.

Arist. Because the Dilation of the internal Air, which descends into the Pump, pushes the Piston downward, with a Force almost equal to the Resistance of the external Air.

Eud. The more I pump the internal Air, the more the Piston seems to resist. —

Arist. The more you pump the internal Air, that which remains has a freer Space, and is more dilated; the more it is dilated, the less Force it has to second you; the less it seconds you, the more you feel the Resistance of the external Air; the more you feel that, the more the Piston seems to resist.

Eud. I draw the Piston again; you see a small Rain, and the Sides of the Receiver tarnished and obscured within.

Arist. The internal Air, which is rarified suddenly, pushes and shakes the imperceptible Vapors which flutter in the same Air; and if it is in a certain Degree of Rarefaction, it has no longer Force enough to sustain them. Those Vapors being united in the Succession, and in their Fall, fall down in Rain. Many of them

whole Atmosphere. Thus we find Mercury sustained to the same Height by the elastic Force of Air, included in a Glass Vessel, no Way communicating with the external Air, as by the Weight of the whole Atmosphere. *Id. Ibid.*

The Effects of the Elasticity of the Air are like those of its Gravity; and included Air acts by its Elasticity, just as Air not included by its Weight.

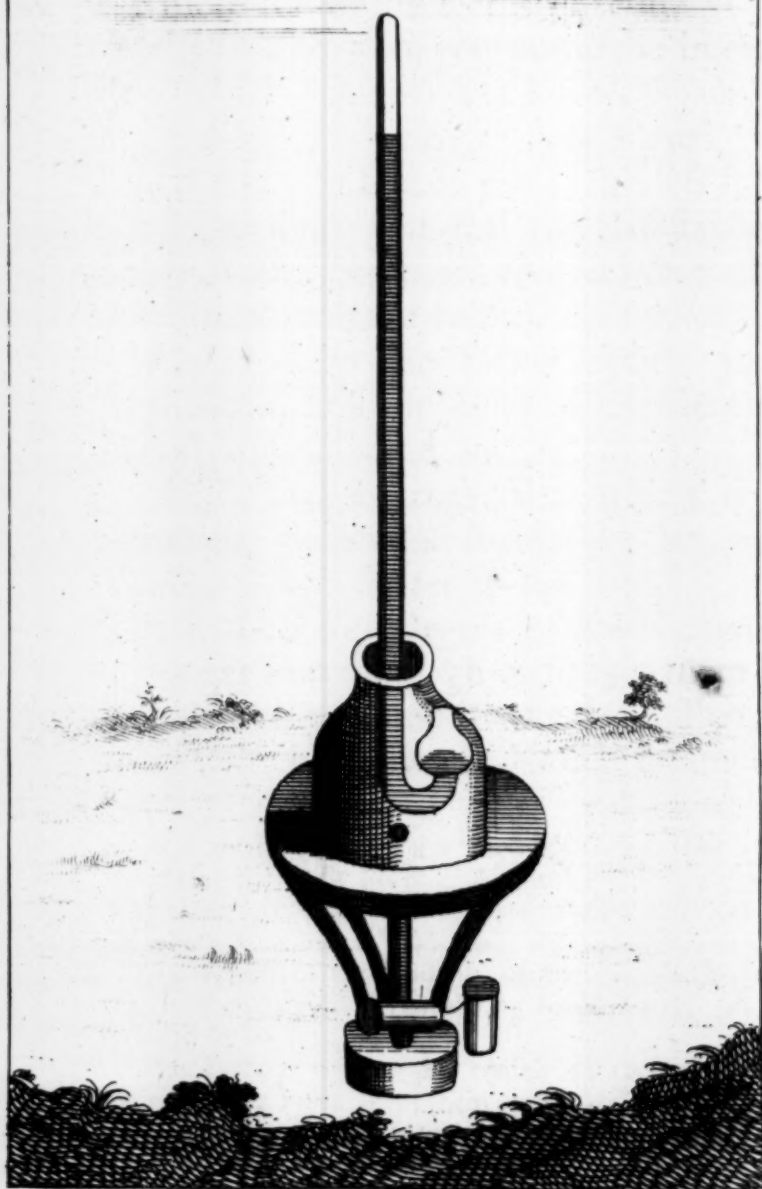
The Particles whereof Air consists do not touch each other; their repelling Force keeps them apart; and the Force wherewith they endeavour to recede, increases in the same *Ratio* wherein the Distance of the Particles is diminished.

being

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fig. 30.



being thrown upon the Sides of the Receiver, tarnish it inwardly and obscure it, shutting up the Passages of Light.

Eud. When the Piston has descended, I leave it at Liberty. It ascends as of itself.

Arist. Because it is thrust back by the external Air, without finding in the rarefied Air of the Barrel, a Resistance equal to the Force which thrusts it back.

Eud. I let the external Air enter again into the Receiver by turning the Key, and by the Pipe of Communication; the Receiver is detached and obeys.

Arist. Because the Air being returned, pushes it upward with an elastic Force, equal to the Action of the Gravity of the external Air, which pushes it downward.

Eud. I have made the Tube of a Barometer pass thro' the bored Top of another Receiver, which I place upon the Copper-Plate instead of the first. You see the Mercury at its ordinary Height, in a very small Space, *Fig. 30.*

Arist. The internal Air retains it there by its Spring.

Eud. I pump out the Air, and the Mercury descends.

Arist. Because the dilated Air, which remains, having no longer the same Force, does no longer sustain the same Weight.

Eud. I let the Air enter again. The Mercury ascends again.

328 CONVERSATION XXIII.

Arist. The internal Air, being established again in its former State by this Return, has the same Force which it had before; the same Force produces the same Effect, replaces and sustains the Mercury at the same Height.

Eud. I place under another Receiver an old and shrivelled Apple, and a flaggy Bladder, whose Neck is well tied; I pump the Air. — The Bladder is inflated, and the shrivelled Apple appears plump to the Eye. — Is it not an Apple fresh gathered?

Arist. The Air, which is within the Apple and Bladder, being no longer compressed by the external Air, is dilated; and by its Dilatation inflates the Bladder, and produces this Species of new Fruit.

Eud. Let us permit the Air to enter again, the inflated Bladder becomes flaggy, and the Apple is shrivelled and loses its new freshness.

Arist. The Air which enters, being more compressed and stronger than the dilated Air of the Apple and Bladder, presses and contracts their Extremities. Thus the Bladder and Apple resume their Wrinkles.

Eud. Let us place a Glass of Beer under a small Receiver. — Pump the Air. — Here are Thousands of small Bubbles which ascend. — Pump again. — The Beer froths.

Arist. Thousands of Particles of Air, which remained shut up and intangled in the Interstices of the Beer, being at last delivered from
the

the Pressure of the superior Air, are disengaged, dilated and inflated. Being inflated, they have thereby much more relative Levity; and being forced to ascend by the Gravity of the Beer, they rapidly reach the Surface of the Liquor. Every Bubble of Air raises up, and carries along with it a Pellicule, a very minute Surface of Liquor, and is wrapped up in it. Hence those small, white and numerous Bubbles, which swim upon the Beer. Thus the Beer lathers.

Eud. Instead of the Beer I put a large Glass, almost half full of warm Water. I pump out the Air at different Times. The Water rises up with great Bubblings, springs up into the Vacuity, and boils more strongly than if it were over a great Fire. The Spirit of Wine would produce the same Effect.

Arist. That which makes the Beer lather, makes also Water and Spirit of Wine to boil. Spirit of Wine and Water are impregnated with Air. This Air, being eased of half the Weight which pressed it, is set at Liberty, and unfolds its Spires and Plates. An Excess of relative Levity makes it yield and ascend hastily. Its rapid Motion bears up, and throws out a Number of liquid Surfaces. Thus warm Water and Spirit of Wine boil without Fire.

Eud. But why does warm Water boil rather than cold Water?

Arist. Because the Parts of warm Water being agitated, divided and diminished by the
Action

330 CONVERSATION XXIII.

Action of the Heat, leave the Particles of Air, already heated a little and dilated, freer Passages to disengage themselves.

Eud. The Bubbles of Air augment in Bulk, and in Proportion as they approach the Surface.

Arist. Because in Proportion as they ascend, having less Weight to sustain, they are dilated.

Eud. Let us pierce the End of an Egg. — I put it into a small Glass, with the pierced End downward. Pump out the Air. — You see the liquid Matter come almost all out from the Shell. — Let the Air return. — The Matter disappears.

Arist. After the issuing out of the external Air, the Spring of the internal Air has dilated the liquid Matter, and driven it out of the Shell. After the Return of the external Air, the internal Air being shut up in its former State by a superior Force, has left the Place free to the liquid Matter. This Matter being thrust back, reenters the Shell, where all is in *Æquilibrium* with the Air of the Receiver.

Eud. Pour Water into a larger Glass. Upon the Surface of the Water I put a Sponge impregnated with Water, and cover it with the Receiver. Pump out the Air. The Sponge is somewhat elevated. Permit the Air to enter again. The Sponge sinks. Pump again. The Sponge ascends and swims above.

Arist. 1. When I pump the first Time, the Air contained in the Sponge finding itself more free,

free, is dilated and comes out, in Part at least. What Air remains in the Sponge, altho' it be much weaker than before, is sufficient to give a greater Bulk to the Sponge by its Dilation. This Excess of Bulk renders it lighter. Being lighter, it ascends a little. 2. I make the external Air to re-enter. This Air being much stronger than the diminished and weakened Air of the Sponge, compresses it. By compressing it, the Sponge is contracted into a less Bulk, and more compact than it was before. By that Means the Sponge becoming more weighty than an equal Volume of Water, sinks. 3. Whenever I pump again, the internal Air not having the Pressure of the pumped Air to sustain any longer, is dilated again, and dilates the Sponge. The Sponge being dilated and more light, recovers the Surface of the Water. I need only continue the same Mechanism, and the Sponge will continue its Diverfion by the same Reason.

Eud. Do you see, *Aristus*, this other Species of small Receiver? It is a Cupping-Glass. They apply it full of the light Flame of a little Flax upon Cicatrices made on the Shoulder of a Man in a Lethargy. Whenever the Flame is extinguished, the Flesh, which answers to the hollow of the Cupping-Glass, is inflated, and the Blood thrown out.

Arist. The Flame expels much Air from the Cupping-Glass, and rarefies the rest in an extraordinary Manner. It is extinguished? The
Air,

332 CONVERSATION XXIII.

Air, which is in the Blood and Flesh, and which has lost nothing of its Force, is stronger than the dilated Air of the Cupping-Glass, and is extended. This Extension inflates the Flesh, and rarifies the Blood; the Blood being rarified is thrown forth.

Eud. One Fact more of the Spring of the Air, which pleases the Eye without hurting the Imagination. You see this small enamelled Figure of a Man (*a*), *Fig. 31*. It is full of Air. It has in the Leg a small Eminence, bored through and through. I fill this Glass-Tube with Water by the lower End. The little Figure immediately swims, then it descends, ascends again, rests, whirls about, dances, and repeats the same Scene at Pleasure.

Arist. Let us see the Experiment.

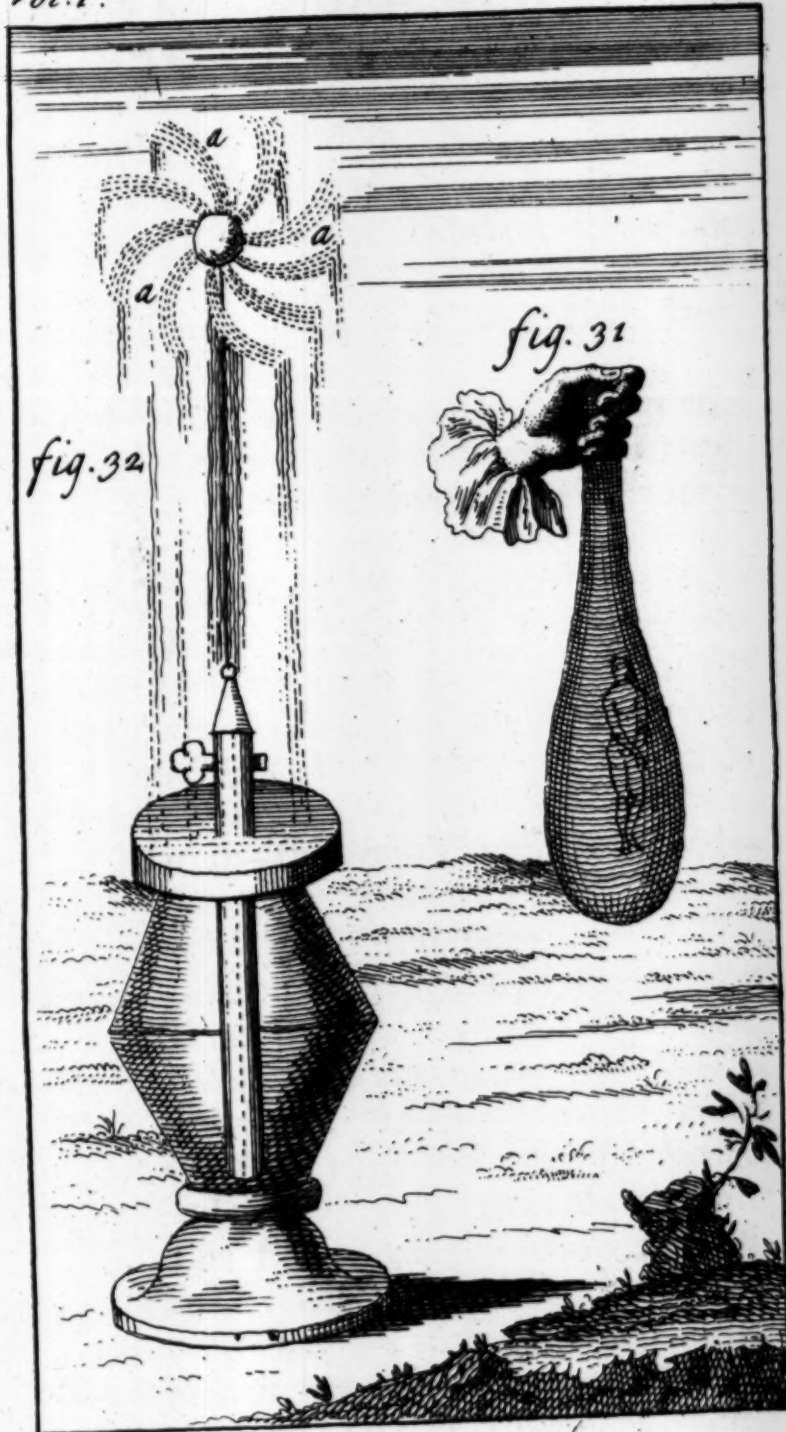
Eud. You see the little Figure swim above.

Arist. The Reason is, because the internal Air makes with the enamelled Picture, a Bulk lighter than an equal Bulk of Water.

Eud. I press with my Thumb the Orifice of the Tube. The little Man is plunged to the Bottom.

Arist. The Water being compressed by the Action of the Thumb, enters into the little Hole of the Leg, compresses the internal Air, and renders the Bulk more heavy. Being more heavy, it sinks to the Bottom.

Eud. I cease to press the Water, always closing up the Orifice of the Tube with my Thumb.





Thumb. The little enamelled Man ascends again.

Arist. The Water, which ceases to be compressed by the Thumb, yields to the Spring of the internal Air, which is dilated; it comes out of the Leg. The Figure becomes lighter. Being lighter, it is thrust back toward the Surface of the Water.

Eud. While it ascends again, I say but one Word, and it rests in the Middle of its Journey.

Arist. The Word alone would be very ineffectual; but you stay your Thumb upon the Surface of the Water; you press it so, that it flows into the small Hole of the Leg, precisely in such a Quantity, as is necessary for putting the enamelled Figure into an *Æquilibrium*. This, I believe, is the Charm, which at once stops it half Way.

Eud. Is it also then my Thumb, which determines it at once to whirl about, and to dance in the Middle of the Tube?

Arist. While at different Times you sink and raise your Thumb with a certain Quickness, the Air and Water are alternately victorious in the Hole of the Leg. In this Sort of Conflict they hastily dash against the small Eminence, and give it a Direction to go toward the Right or Left. The Figure cannot follow this Direction; the Obstacle of the Water impedes it. But by turning about, it may yield itself to the Motion which it has received; it turns about according to your Laws of Motion, it whirls round,

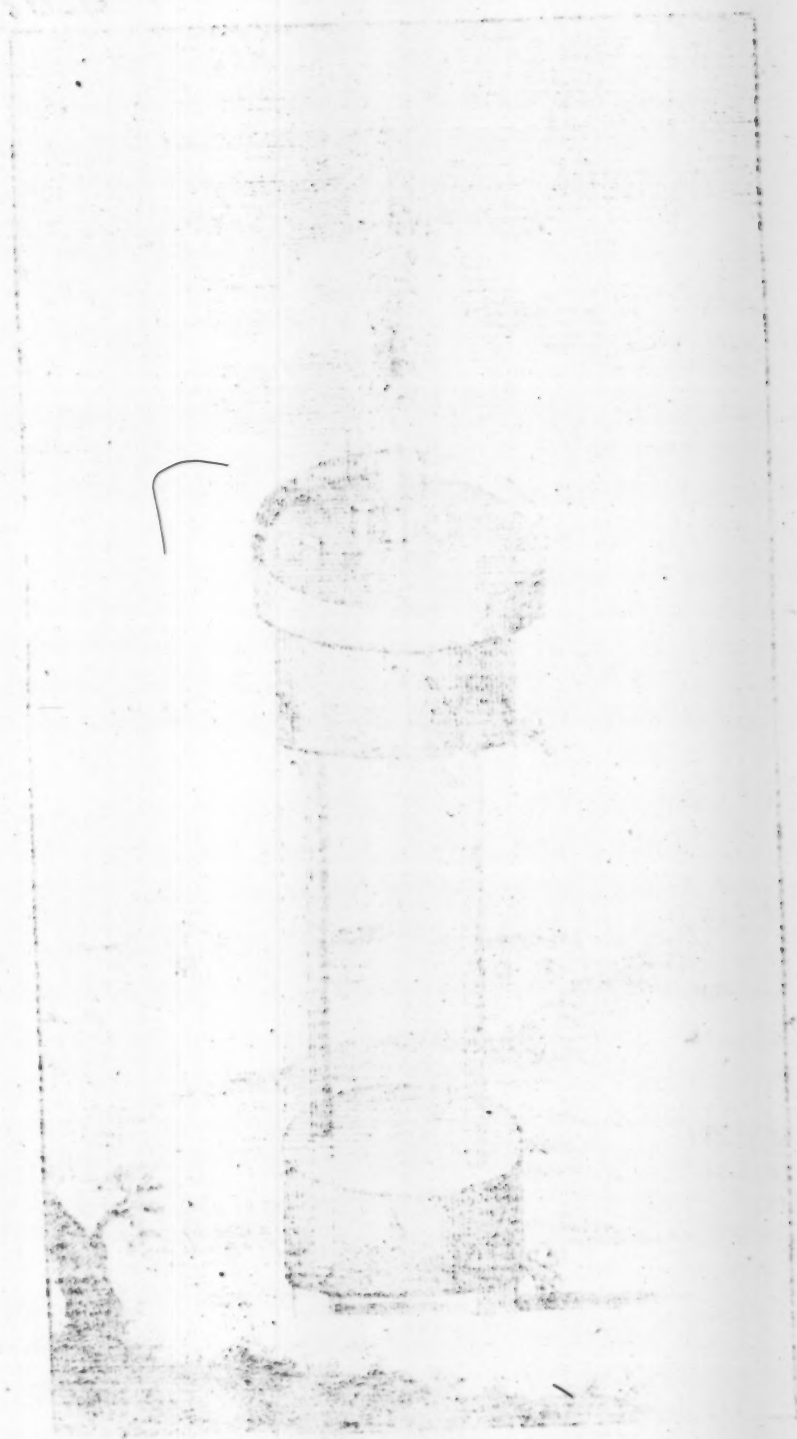
334 CONVERSATION XXIII.

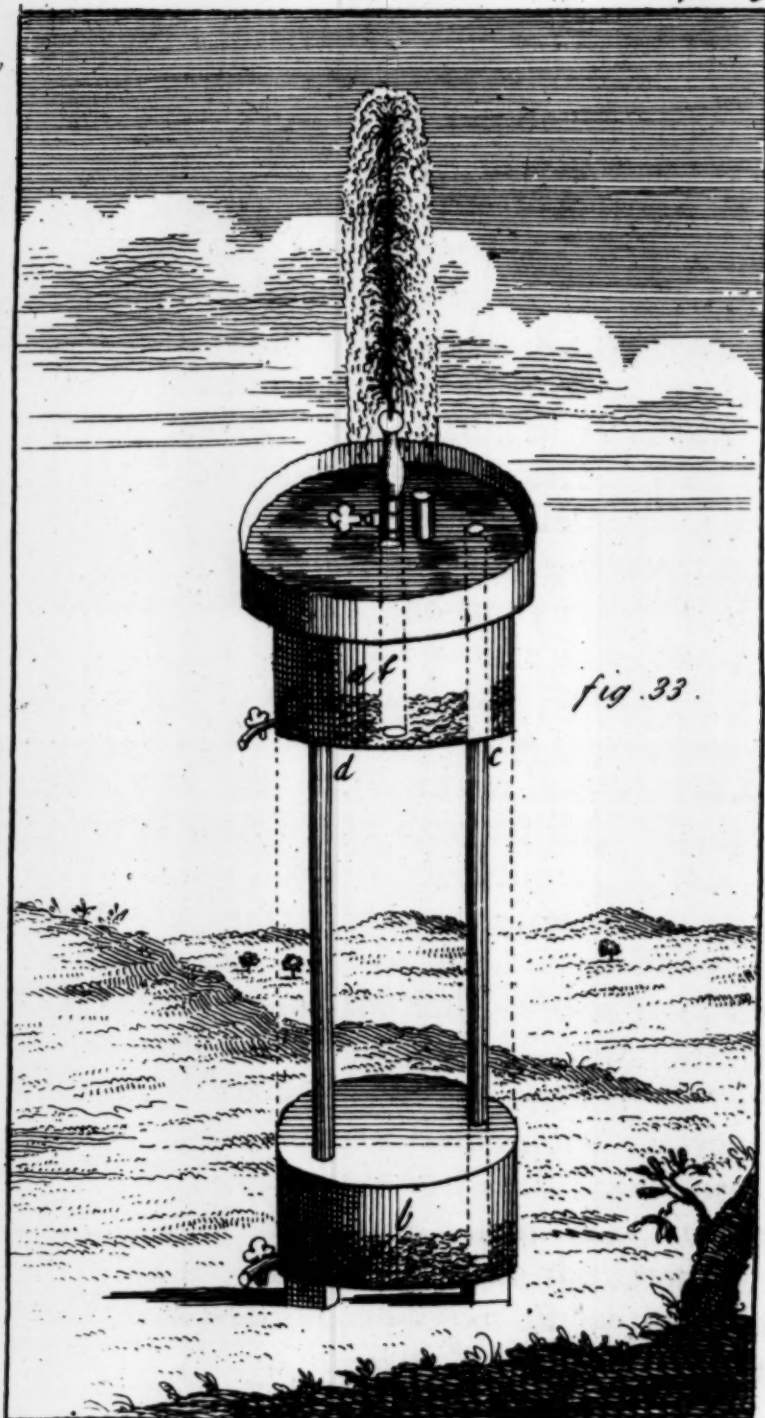
round, dances mechanically; and this is continually in Appearance with some Success.

Eud. Now with the Breath alone, or with a Pair of Bellows, let us condense the Air upon the Water in a close Vessel; out of which the Water may spout by a Tube, one End whereof descends as far as the Bottom of the Vessel, while a moveable Key opens and shuts the other End, *Fig. 32.* The Water spouts up, and makes an artificial Fountain. Upon the Water spouting up I place a Wax-Ball, or rather a Copper-Ball, hollow and very thin. The Water which touches it, sustains it, makes it to turn about, and turns about itself, till it get off and be thrown out in Streams, which are like so many Tangents (*aaa*).

Arist. The Water being compressed by the internal Air extraordinarily condensed, and thrust back by the external Air, which is only in its ordinary Condensation, yields to the greater Force, overcomes the weaker, and is darted out into the Air. The Force of the Water sustains the Ball, which is of Copper, but very thin, and full of Air. The Water which strikes it, but not precisely in the Middle, makes it turn round; and flowing upon the Surface, where it sticks a little, turns itself round, till the Force which makes it turn, detaches it. Then it follows the second general Rule of Motion, and goes off by the Tangent, as all Bodies do which are moved circularly, whenever they are at Liberty.

Eud.





Eud. Let us place the same Vessel over the Fire, without condensing the internal Air; the Water spouts up.

Arist. The Heat dilates the internal Air; the Air being dilated forces the Water to spout up. This is a Species of *Æolipile*.

Eud. Imagine now, or rather consider two Pipes of Tin, perpendicular to the Horizon, open at the two Ends, and sunk into two Sorts of Drums of the same Matter (*a, b,*) *Fig. 33.* The one of the Tubes (*c*) pierces the superior Drum (*a*), quite through, and descends almost to the Bottom of the inferior Drum (*b*); the other Tube (*d*), which only penetrates the superior Plane of the inferior Drum, penetrates into the other Drum as far as the superior Plane. In the Middle of the superior Drum is a small Tube (*e*), which descends almost to the Bottom of the same Drum. This Machine they call the Fountain of *Heron*. By the Tube in the Middle, I fill the upper Drum with Wine. I leave therein no Passage but through a little pyramidal Pipe. Then by the Pipe which pierces the upper Drum quite through, I pour in Water into the lower Drum. There is Wine which issues out of the other, and springs up into the Air. Is it not Magic that makes Wine to spout out from the Bosom of Water itself?

Arist. The Water being poured through the Tube fills the inferior Drum. When the Drum is filled with Water, the Air which filled

336 CONVERSATION XXIII.

it removes through the second Tube, is diffused and condensed above the Wine in the superior Drum. The Wine being impelled by the Spring of the Air extraordinarily condensed, and finding a Passage by the inferior and the superior Ends of the pyramidal Tube, issues out with so much the more Velocity, as it passes from a larger Place through a straiter Vent. It springs up, and is darted far above its Source; and the Spring of the Air is the secret Charm, which seems to make the Wine spout out from the Bosom of Water itself.

Eud. After this, nothing seems to be more evident in natural Philosophy than the Spring of the Air; a Spring so much the more perfect, because the Time of its Tension does not change it, as that of Wood or Steel. For *M. de Roberval*, of the Royal Academy of Sciences, having let his Air-Gun remain charged with condensed Air for the Space of sixteen Years; this Air, being at last set at Liberty, appeared to have lost nothing of its elastic Force, and produced the same Effect which it would have done at first^m.

Arist. I do not demand a Demonstration; I would only have a plausible Reason of this Fact. *Eud.* 1. The Air being a more simple Body than other elastic Bodies, ought to be changed with the greater Difficulty. 2. The subtile Matter flowing alone through the Pores

^m Hist. del'Acad. 1695. p. 368.

or Interstices of the Air, without being charged with Air, or Spirits of Nitre, or grosser Corpuscles, as it is when it penetrates other Bodies, ought to damage the Air less. 3. In a Word, the small Branches of condensed Air make a Mass, whose united Forces preserve it from the Action of the subtile Matter. Hitherto we have seen, I think, Facts enough peculiar to Gravity; and Facts enough peculiar to the Spring of the Air; let us see some Facts which seem to regard both the Gravity and the Spring at the same Time.

Arist. Must I my self, *Eudoxus*, interrupt a Conversation, wherein you give me so much Pleasure? But a Duty of Friendship calls me elsewhere. At one o' Clock in the Afternoon I shall wait on you here.

Eud. An honest Man does not neglect a friendly Office; should a Philosopher then decline it? Philosophy knows how to accommodate itself to the Laws of sound Morality.





CONVERSATION XXIV.

*Upon divers curious Effects of Gravity
and Elasticity of the Air in different
Bodies.*

Eud. **W**ILL you believe it, *Aristus*? The Air insinuates itself, and is, in some Sort, dissolved in Water; especially in boiled Water. Boil some Water for about an Hour. Let it cool again: Then fill a Phial with it, whose Belly is very round. Close it up with your Finger in such sort, that you may let the Air enter into it, about the Bigness of a Filberd. Turn it topsy turvy. Plunge the End of it into a Glass full of the same Water: In three or four Days this Air will be almost wholly lost in the Liquor. I put a small Bubble of Air of two or three Lines into a Glass Phial, full of River Water, which has not boiled. The Bubble of Air is also lost in the Water; but more than fifteen Days are required, to make it disappearⁿ.

Spirit of Wine, out of which the Air is gone, sucks it up in less than three Hours*.

ⁿ Mariote de la Nature de l'Air, p. 97. 106.
ote, p. 132.

* Mari-

Arist.

On divers Effects of Gravity, &c. 339

Arist. In this Experiment the Weight and Pressure of the external Air, which can elevate 32 Foot of Water, pushes the Water of the Phial against the Bubble of Air, which swims above. The Bubble of Air thrusts back the Water by the Efficacy of its Spring. In this reciprocal Action the Particles of Air gradually divide the Particles of Water; the Particles of Water divide the Particles of Air: The one finds Access into the Interstices of the other. Thus the Air penetrates, is dissolved, and lost after some Days in boiled Water.

By the same Reason, the Air is lost in Water, which has not boiled: But the Effect is not so speedy, because the Particles of boiled Water being divided and diminished by the Agitation of the Heat, find a more easy Access into the Interstices of the Particles of Air, and mutually afford them more easie Access into their own Interstices, than Water which has never been boiled. By this one sufficiently understands why Spirit of Wine sucks up Air so quickly.

Eud. Nevertheless Air is mixed more difficultly with Water, than Wine. I place in the Bottom of a Vessel, full of Water, this Bottle full of Air, whose Neck is three or four Lines wide. No Air comes out of it, no Water enters into it. I fill the Bottle with pure Wine. The Water penetrates the Wine, and the Wine the Water. You see it open itself a Passage

340 CONVERSATION XXIV.

through a heavier Liquor, and gain the Surface of the Water °.

Arist. The Particles of Air are small, minute, and fine; but ramous, according to the Definition which you have given of them. Wherefore those Particles intangled in one another, in the small Neck, make a small uniform and smooth Surface, and sustain the Water by their Spring so much the more easily, because the Water pressing equally and at once all the Parts of the small uniform and smooth Surface finds no Access into it, nor makes Columns unequally weighty with the inferior Air, which might give Place to one another. Hence the Water does not enter into the Bottle; nor does the Air come out of it. But the Particles of Wine, as well as those of Water, are more gross, solid, and less uniform. They make a Surface less smooth, afford Access into one another, rub, touch, and agitate one another in more Parts, and make more Columns of unequal Force. Hence Water being heavier than Wine, insinuates itself, descends, and makes the Wine to ascend by small Streams.

Eud. But finally, do you believe that the Air has the same Bulk in Water as without it?

Arist. It ought to be more contracted in Water, since therein it is charged with a greater Weight.

• Mariote de la Nature de l'Air, p. 94.

Eud.

On divers Effects of Gravity, &c. 341

Eud. Accordingly *M. Mariote* has observed that the Air, which he had exprest from a Drop of hot Water, contained, when cold again, eight or ten Times more Space than a Drop of the same Water ^P. According to the Principles and Calculation of this skilful Member of the Academy, the Air may be dilated more than four Thousand Times beyond what it is in Liquors and near the Earth ^q.

Hence, Air which is more condensed in Liquors, Plants, Flowers and Fruits, than without them, causes Evaporations by the extraordinary Effects which it makes in Order to extend itself; and at last contributes to the Corruption of those Bodies. Wine loses its Spirit; Flowers decay; Fruits lose their Sap, become insipid, and putrifie. These Bodies commonly are better preserved in close Places. Herbs, which would wither in less than an Hour in the open Air, remain fresh two or three Days when pressed between two Linnen Cloths. Put Cherries into a small Phial in the Month of *June*. Close up the Mouth with red and viscous Wax; and at the End of nine Days you will find the Cherries still intire, and of the same Colour^r. The Leaves which compose the *Calix* of a Tulip, preserve their Shades and the Liveliness of their Colours in a Book. Blood contained in a small Matrafs hermetically seal-

^P Mariote de la Nature de l'Air, p. 111.
la Nature de l'Air, p. 170, 177.

^q Mariote de
^r Ibid. p. 223.

342 CONVERSATION XXIV.

ed up, has been seen to preserve a fine Colour and its Liquidity for the Space of ten Years^s. The Reason is, because the Air of those Bodies, finding more Resistance made to its Dilatation in close Places, produces fewer Evaporations, and the Action of the external Air, commonly charged with heterogeneous Corpuscles, causes less Change in it.

But does this Air which insinuates itself so subtly into different Bodies, pass through Paper? Here's an Experiment which will convince us. — Upon the upper End of a Barometer, whose two Ends are open, I glue a small Circle of Paper, with a Mixture of Wax and Rosin; so that the Air cannot enter but through the Paper itself. I pour between 15 and 16 Inches of Mercury into the Tube, and invert it after the usual Manner. The Mercury descends suddenly to a certain Point; then it seems to stop. But in a short Time it descends more slowly, till it be almost on a Level with the Mercury into which the lower End is plunged^t.

Arist. 1. The Mercury descends suddenly to a certain Point, because with the Spring of the internal Air it makes a stronger Column than the external one. 2. It stops in Appearance; because the internal Air being dilated, and the Mercury having fallen down, are in *Æquilibrium* with the external Air. 3. But in

^s p. 221.

^t Mem. de l'Acad. 1714. F. 59.

a short Time the Mercury begins again to run gently; because the external Air enters through the Pores of the Paper. 4. The Mercury descends gradually to the Level, because the least Excess of Force in the Air is sufficient to find some Passages in the Paper.

Eud. If I make Use of fine Paper, the Mercury descends the more swiftly.

Arist. That is because in the fine Paper the Air finds more open Pores.

Eud. But proportionally as the Mercury descends, it descends more slowly.

Arist. In Proportion as it descends, the Column, which sustains it, having less Mercury to sustain, supports the Column, which ponderates upon the Paper, so much the more. This being more supported, makes less Effort in Order to pass through the Paper, which opposes its Passage. With a less Effort, it penetrates more slowly. The Mercury being impelled more slowly, descends so much the slower.

Eud. I soak the Paper with Water. The Mercury remains sensibly suspended, until the Paper begins to dry.

Arist. Because the Water stops up the Pores of the Paper, and hinders the external Air from entering sensibly into the Tube.

Eud. Indeed, Seamen, when they have a Mind to sail more swiftly, wet the Sails; that so the Water stopping the Interstices of the Sails may shut up the Passage of the Wind, and that the Wind or agitated Air may push the

344 CONVERSATION XXIV.

Sails with all its Force, and no Part of it pass unprofitably through the Pores.

But the Air, which is in the Pores of the Paper, does not hinder Water to pass through; why then does not Water let Air pass through?

Arist. Air, which is finer than Water, is not sufficiently attached to the internal Surfaces of the Paper, nor has Consistence enough to sustain the Gravity of Water that is more weighty and solid; it lets it pass through. The Water being more solid and gross, which wets, soaks, and lengthens the Paper, is sufficiently supported by the unequal Surfaces of the Pores; it has Consistence enough for sustaining the Gravity and Effort of the external Air, and stops it.

Eud. Is the Air, say you, finer than Water? Nevertheless these two Liquids being protruded by the same Force, the last in certain Circumstances passes through Places, which the first cannot. Instead of Paper I cover the Top of the Barometer with a Hog's Bladder. The Air alone does not penetrate the Bladder, but Water penetrates it^u.

Arist. That is, because the Excess of Solidity, which is in the Particles of Water, prevailing over the Excess of Tenuity which is in the Particles of Air, those have Motion and Force enough to open the Texture of the Bladder, while these, being retarded by their small

^u Mem. de l'Acad. 1714. p. 61.

On divers Effects of Gravity, &c. 345

Branches, have not. In short, Water wets, soaks, and lengthens the Bladder.

Eud A Fact renders your Sentiment plausible. The Particles of Water, which penetrate the Bladder, bring Air into the Barometer*. This Air they contain in themselves: Therefore they are more gross than the Particles of Air: Notwithstanding they pass through Interstices, which the Particles of Air alone do not pass through; therefore it is the Excess of the Solidity of the first, which makes them find a Passage, where the other find none, notwithstanding their excessive Smallness.

Hitherto we have spoken of the gross Air, which forms Speech itself, as we shall one Day see. Let us conclude our Conversation with a Fact which respects a finer Air.

With a Tube they take up a little of the melted Matter, whereof Glasses are made†. You let it run and fall into a Pail full of Water; and because this Matter is very viscous, the inferior Part being thicker and heavier flows

* Ibid. p. 62.

† Because Glass is a Body which has a Power of Springing; it is probable, that this Glass-Drop is broke in the same Manner, as a Steel Bow bursts in Pieces sometimes, when it is loosened on a sudden, viz. by the too great Celerity and Force of that Motion, which arises from the mutual Attraction of its Parts. For its Parts from the Center to the Circumference, seem to be like so many Bows bent. And thence perhaps it is, that after it is burst to Pieces, its Fissures are disposed like so many *Radii* drawn from the Axis to the Superficies, as Mr. *Hook* observed in a Glass Drop covered over with Glue: See *Hook's Micrography Observ.* 7. *Clarke's Robault.*

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346 CONVERSATION XXIV.

without being wholly detached, and is lengthened out in Form of a Tear. This sort of Tear is sometimes called the *Lacryma* of *Prussia*, and sometimes the *Lacryma* of *Holland*. The Tear, which falls all red into the Water, is cooled therein; here is one, *Fig. 34*. I strike with an Hammer the thickest Part of it (*d*), or the Head of the Tear, without its breaking.

Arist. I am not astonished at it. The Parts which are struck, being disposed in Form of a Vault, and supporting one another, ought to be Proof against your Blows.

Eud. But I break the finer Part (*b*), or Tail of the Glass Tear. — You see the whole Tear fly asunder at once into white Dust two or three Foot round about *.

Arist. Doubtless the Fact is surprizing. Notwithstanding I think that, by Favour of the Lights which I owe to you, I discern the Cause of it in a finer Air, which suddenly passing from a larger Space into the open Pores of the broken Tail, runs rapidly into a Thousand and Thousand small Cells, which grow wider and wider toward the Middle, then narrower and narrower toward the Extremities, and which the Irruption of the Air drives asunder by the Efficacy of its Spring and accelerated Motion.

* *Mar. de la nat. de l'Air*, p. 64.

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On divers Effects of Gravity, &c. 347

Whenever the Tear falls into the Water, the Particles of its Surface being suddenly seized with the cold of the Water, are cooled again and hardened immediately, while the internal Parts being extraordinarily dilated by the Heat and by an Air that is dilated itself, are still red. The Parts of the Surface being cooled at once, are neither drawn near enough one another, nor well fastened together, nor can they approach the Center any more. Hence, when the internal Parts come to be cooled, in Proportion as they are distant from the Surface, they leave smaller Interstices toward the Surface, and greater toward the Middle. These Interstices only contain a rarified Air: For which Reason, when the fine Air finds an Entry through the Pores of the broken Tail, it enters briskly into the internal and more spacious Interstices; thence it drives out a more subtile Matter; and from the Middle of a Thousand Cellules, the small *Laminæ* of fine Air are rapidly hurried toward the Extremities, with an Acceleration of Velocity, and like so many Wedges, through Passages which constantly grow straiter. This impetuous and sudden Effort enlarges the Pores, and separates the Parts, already but badly united. The Suddenness of the Shock darts out the Particles toward a Thousand different Parts. Thus the Drop is crumbled into Dust.

This Reason seems to me so much the more probable, because the Air, which suddenly
finds

348 CONVERSATION XXIV.

finds Access through the lower End of a Barometer in an Experiment, throws the Mercury upward with so great a Violence, as you were saying not long ago, that sometimes it breaks even the Tube itself.

Eud. Many Circumstances confirm your Sentiment. For 1. The Tears, which are cooled in the Air, do not break. Why? Because their Particles, which are cooled slowly, almost in the same Time, and equally, are united, and make the Air within resume a Condensation, equal almost to that of the Air without.

2. Drops that are nealed, no more break than those cooled in the Air; because the Air from without finding the Matter of those Tears softened by the Heat, makes it re-enter within, compresses the internal Air, and by that Means prevents the Irruption and impetuous shaking of the fine Air, which breaks the Drops that are cooled in Water.

3. Put a Pin into the large Bubbles, half polished with Press-Sand, upon a Plate of Steel, or else with very fine Powder of Emery: Sometimes the Tear is broke; the Pin which makes the external Air to enter, causes the breaking of the Drop. Sometimes also it is broken when the Pin is no longer in it, and when one ceases to make any more the least Effort y.

On divers Effects of Gravity, &c. 349

The Drops of Glass are broken in the Air-pump with a greater Effect so as to produce Light^z; because there remains fine Air enough to break them by its sudden and violent Irruption, and because there is much less gross Air, which might hinder the scattering of the detached Fragments.

Finally, when you desire it, *Aristus*, we will see in Syphons and capillary Tubes some singular Facts, wherein the Gravity and Spring of the Air, and the subtile Matter itself, appear to have a great Share.

^z Hist. de l'Acad. 1692. p. 307.



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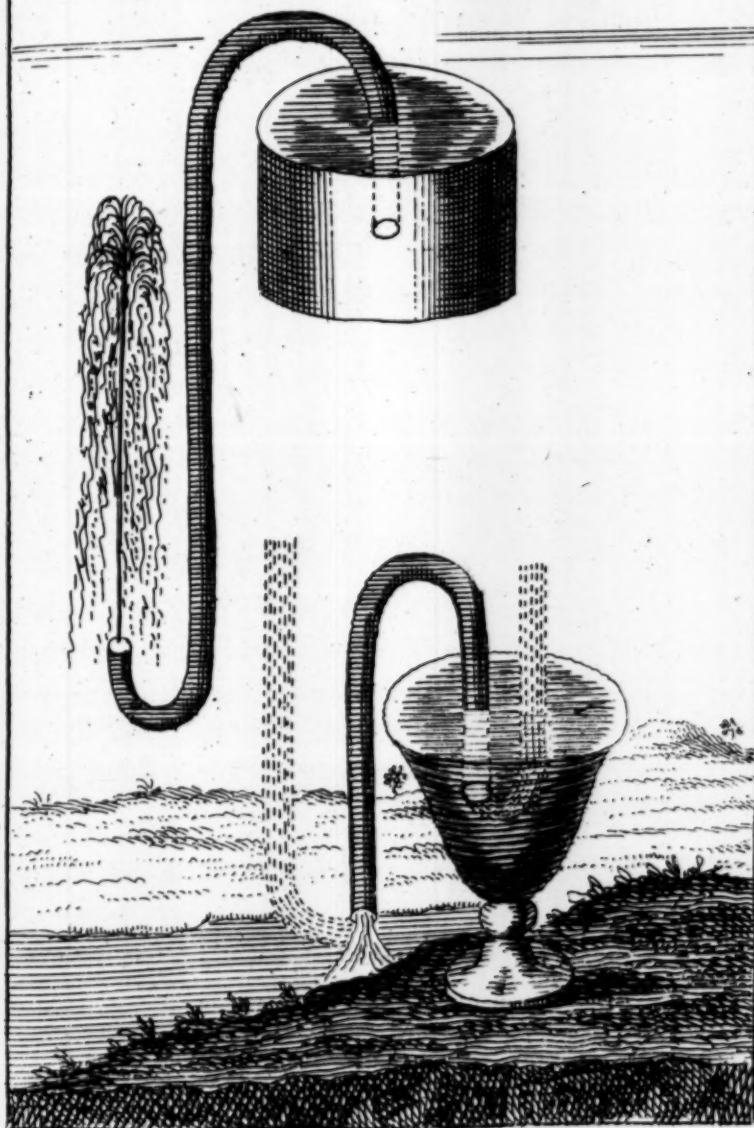
CONVERSATION XXV.

Concerning Syphons and Capillary Tubes.

Eud. **L**ET us continue our Experiments,
Aristus. I take a Syphon. It is a crooked Glass, one of whose Branches is shorter than the other, *Fig. 35.* I put the shorter one into the Water. The Water remains calm. I suck the Air from the two Branches. You see the Water flow.

Arist. Before you suck the internal Air, it opposes the Elevation of the Water with a Force equal to the Force of the external Air, which presses and strives to elevate the Water in the Syphon; and the Water remains in *Æquilibrium* between two equal Forces. But after you have sucked the internal Air, the Water that answers to the Syphon being pressed by the Weight of the external Air, which would elevate it to 32 Foot, and being no longer retained by an equal Force, ascends through the small Branch as far as the Communication of the two Branches. Then the Efficacy of the Pressure, which makes it ascend, and its own Weight, make

Fig. 35



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make it descend and flow through the longer one.

Eud. Thus the Syphon, set a going in the free Air, lets the Water run out more slowly in an Air-Pump, in Proportion as you pump out the Air; and when the Air fails, the Syphon stops^a. But since the Column of Air, which answers to the End of the longest Branch, is longer and heavier than the Column which makes the Water at first ascend, why does it not make it to ascend again, or at least detain it suspended?

Arist. The Column of Air, which answers to the End of the longest Branch, is longer: But it has more Liquor to sustain; and this Excess of Liquor surpasses the Excess of the longer Column, in Gravity: Therefore it must give Place, and permit the Water to flow. By the same Reason, the Water will not ascend, if you plunge into it only the End of the longer Branch.

Eud. Nevertheless the capillary or very minute Syphon does not cease to play in the *Vacuum*^b, and Pieces of Cloth, especially when the Cloth is wetted before the Experiment, are full of imperceptible Pipes, which begin to play in the *Vacuum*, and make Liquors to pass from one Vessel into another^c.

^a Hist. de l'Acad. an. 1714. p. 85.
1714. p. 86. Mem. p. 336.

^b Hist. de l'Acad.

^c Mem. de l'Acad. p. 339.

Arist.

352 CONVERSATION XXV.

Arist. The Beginning or Continuance of this Diverſion ſeems a little contrary to the Hypotheſis of the Air's Gravity.

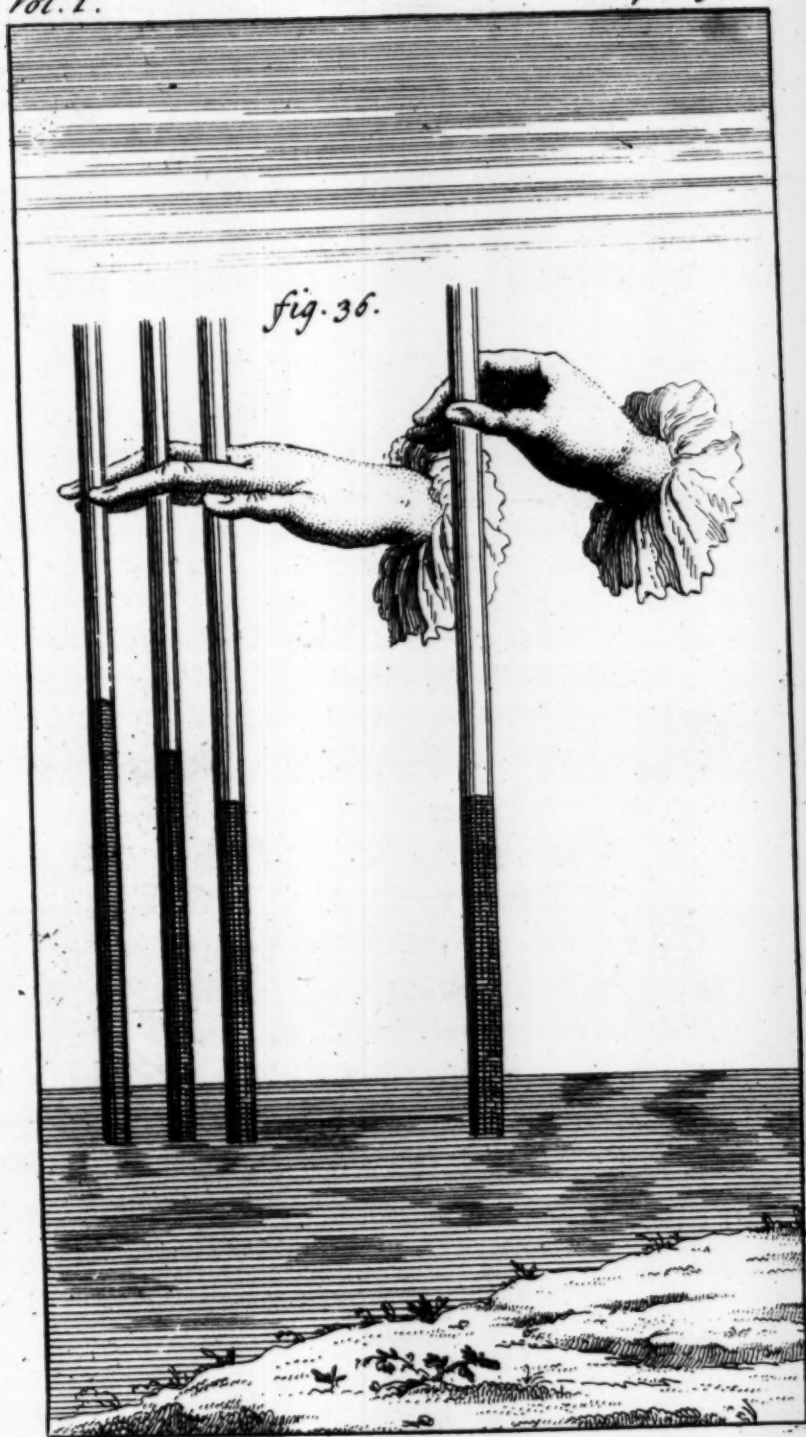
Eud. Nothing in the Main is more conformable to it; and in Order to conceive it, let us try to diſcover firſt why Liquor aſcends, and is ſuſtained above its Level in the capillary Tube, *Fig. 36.* Is it becauſe the external Air bears it up, and the Air which deſcends into the Tube does not act freely upon it, ſo as to thruſt it back, by Reaſon of the Smallneſs of the Space? Some able Philoſophers have been of this Opinion: But, 1. The Air, which finds free Acceſs into the Barometer through the Hole which is made in the Bladder that closes up the ſuperior End, ought to find free Acceſs into a Tube, whoſe Diameter is much larger notwithſtanding its Smallneſs, and to drive downward the Liquor with as much Force as it is pushed upward. 2. Under the Receiver that is void of Air, the Liquor is equally elevated ^d. The ſame Elevation ſubſiſts, and is likewise ſomewhat increaſed ^e, becauſe the Air contained in the Liquor extends it ſtill more by the Exceſs of its Dilatation.

What is it then which cauſes the Elevation of a Column of Liquor in a capillary Pipe above its Level? The mutual Adheſion of the Parts of the Liquor, and the Adheſion of the

^d Mem. de l'Acad. p. 345.
P. 245.

^e Mem. de l'Acad- 1705.

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liquid Column to the internal Surface of the small Pipe; the Spring of the Air contained in the elevated Column, the Viscosity of its Parts, or the Facility which their Homogeneity and Texture afford them of being united to one another; and very probably an Atmosphere, or *Vortex* of subtile Matter which circulates round about Bodies, at least about the greatest Part of them.

In short, 1. The Particles of Water adhere to one another; otherwise, in the Time of Dew we should not see so many Drops of Water suspended upon the Leaves of Plants; the Particles being separated by their Gravity would not compose so many Drops; neither would two Drops of Water be united again into one, as they are, in their first Contact.

2. The Particles of Water stick to Glass, and the mutual Adhesion of the Particles of Water, as *M. Petit* has remarked^f, is less strong than their Adhesion to the Glass. For if one wet a clean Glass, and shake it, many Particles or Surfaces of Water are loos'd from one another, while still the whole Surface of the wetted Glass remains covered over with Water.

3. The Adhesion of Liquor to the Sides of a capillary Pipe is so much the greater, because the Column of Liquor being more fine, touches

^f Mem. de l'Acad. 1724. p. 101.

354 CONVERSATION XXV.

them in a larger Surface with Respect to its Mass.

4. The Adhesion to the Sides of the Tube diminishes the relative Gravity of the adhering Column, since it hinders the Particles of this Column from ponderating as freely upon the Bottom of the Vessel, as the Columns surrounding it. The Column being diminished in Weight yields to the Spring of the Air which it contains in its Interstices, and to the Neighbouring Columns, and ascends until it be in an *Æquilibrium* with them by the Excess of its Height.

In a Word, take away the Adhesion and you hinder or diminish the Elevation. If one cover the inside of the Tube with a Lay of very thin Tallow, the Water does not pass the Level of the other Columns; if it be not covered as far as the Level, the Water ascends above it to its usual Point. Cover precisely one Side, and the Water does not pass the Level on that Side, but on the other.

The Air contained in the Column which is elevated, finding itself relieved by the Adhesion of the superior Parts, bears them up by dilating itself, and carries those above the Level with it, from which it cannot wholly disengage itself. The Viscosity, Texture, and Homogeneousness of the Parts is the Cause why they are united, and sustain one another, whenever they can touch; touching one another

other in a larger Surface, they leave the less Fluid capable of opposing their Union.

Before the Experiment, wet the inside of the Pipe, the Water ascends the more. It ascends more or less in Proportion to the Texture of its Parts, their Homogeneity its Adhesion to the Parts of the Glass, and the internal Air. Hence Water sometimes ascends three or four Inches above its Level, while lighter Liquors are elevated much less. It ascends higher in Tubes of a smaller Diameter, in which the Columns are more supported, having a larger Surface in Regard of their Mass. The Water also ascends higher in Tubes, which are more plunged into Water; because a greater Part of the elevated Column is sustained by an heavier Column, composed of Air and Water; a Case which cannot be explained by the Inequality of the Pressure of the external Air.

Moreover it is very probable, as *M. de Mai-
ran* conjectures^h, that the Magnetic Virtue of Bodies does not only respect the Loadstone, Iron, and some other electric Bodies, but the most Part of Bodies, after a Manner more or less perceptible. If they have their Atmosphere or *Vortex* of subtile Matter, which flows from their Pores, those which will allow Access to the same Matter, and whose Vortices

^g Mem. de l'Acad. 1705. p. 245.
1724. p. 13.

^h Hist. de l'Acad.

356 CONVERSATION XXV.

will unite into one common *Vortex*, will attract one another, or being placed against one another, they will immediately join and stick together. Other Bodies by a contrary Reason will repel one another, or not join immediately, nor stick together. Hence Water wets Glass, but Mercury does not. Hence two Drops of Water are confounded with one another, whenever they approach, or in their first Contact; the intermediate Air being expelled by the subtile Matter which passes from the one Drop into the other, runs off; and there is no more *Æquilibrium*.

The expell'd Air flows back, and being joined with the Air behind it, is stronger than the intermediate subtile Matter, which passes freely through the Drops of Water; it pushes and unites them into one. Hence Water ascends more swiftly and higher in the capillary Pipes, being wet. Hence, in a Word, Mercury does not ascend above the Level in capillary communicating Tubes, having no Cohesion with the Glass; and it also remains below the Level, because in Order to pass from the larger Tube into the smaller, and to ascend in it, it is divided with much greater Difficulty than Water. Perhaps also because an Atmosphere of subtile Matter, which comes out of the small Tube, finding in the capillary Column of Mercury a larger Surface in Proportion to its Mass, detaches it more, and gives it more Freedom

to descend, than the Mercury of the larger Tube had.

Arist. I now sufficiently understand the playing of the Syphon in a *Vacuum*. Three Principles independent upon the present Action of the Air's Gravity make it play; the Adhesion of the Column, which answers to the Syphon, and renders it lighter than the surrounding Columns; the Spring of the Air contained in this Column, and the Homogeneousness of its Parts amongst themselves, and with those of the Glass. These Principles cause the Elevation of the Liquor in the Syphon as far as the Curvature in the first Branch, as in the capillary Tube; and the Weight of the elevated Column, seconding the internal Air and the Pressure of the neighbouring and victorious Columns, makes it fall through the second Branch.

Eud. But why do we sometimes see very small Syphons stop in *Vacuo*?

Arist. They stop, when gross Bubbles of dilated Air happening entirely to cut the small Streams of Liquor, hinder their Parts from joining and making a Weight capable of dragging the liquid Column out of the Syphon.

Eud. These small Syphons, which stop sometimes in a *Vacuum*, begin again to run

ⁱ Mem. de l'Acad. 1722. p. 336.

358 CONVERSATION XXV.

of themselves whenever they are replaced in the free Air^k.

Arist. Whenever they are restored to the free Air, the internal Air, whose excessive Dilation hindered the flowing of the Liquor, is contracted; the separated Drops are united again; being united, they drag one another through the second Branch, and make a Weight capable of overcoming the Resistance; and the Syphon runs again as long as it is wet.

Eud. Liquors are diffused in Stuffs, because they are full of capillary Pipes, of small Syphons. The Knowledge of the Mechanism of these small Syphons leads me to understand a very curious Experiment. I soak separately two Slips of whited brown Paper, the one in Wine, and the other in Oil. Then I mix together the Oil and Wine as well as possible.— In these Liquors being mixed, I dip one of the Ends of each Slip of whited brown Paper.— The other, which is the longer, comes out passing over the Brim of the Vessel. — You see the Wine ascend and come out of the Vessel by the Filtre imbibed with Wine, and the Oil by the Filtre imbibed with Oil; each only attracting that Species of Liquor, with which it is impregnated.

Arist. Oil and Wine are heterogeneous Bodies, whose different Texture hinders their Par-

^k Hist. de l'Acad. 17 4. p. 85.

ticles from uniting together, and from touching one another immediately and near enough to drive away the Fluid which may repel them. Perhaps also they have different Atmospheres which repel them. Hence, when the Wine encounters the Slips impregnated with Oil, it is repelled instead of finding any Hold, and freely communicating to the Oil that Pressure which it receives from the lateral Columns, and the Spring of the internal Air. The Oil has the same Fate, when it strikes against the Slip impregnated with Wine. But does the Wine encounter the Filtre that has imbibed the Wine? The homogeneous Parts of the Wine touch one another immediately, are united, and fastened together, without leaving between them any Fluid which might oppose their Union; the inferior Parts being pushed upward by the neighbouring Columns of Wine, and by the Spring of the internal Air, as in the capillary Syphons freely push the superior Parts as far as the Curvature; and at last hurrying one another along by their Weight, they descend through the longer End; by the same Reason Oil runs through the Filtre impregnated with Oil. Thus the Filtration separates two Species of Liquors.

Eud. What has been hitherto said, *Aristus*, in our various Conversations may serve to make us comprehend what concerns Fire.



CONVERSATION XXVI.

Upon Fire.*

Arist. **I**T is cold, and I am glad to meet with you, *Eudoxus*, before a good Fire. But I think I should find still much more Pleasure in warming my self, as you do,
like

* As to the Nature of Fire, there is a great Diversity of Opinions among the modern Philosophers, some contending that it is formed such originally by the Creator himself, at the Beginning of Things; others that it is mechanically producible from other Bodies, by inducing some Alteration in the Particles thereof, the former is maintained by *Homberg*, *Boerhave*, the younger *Lemery*, and *S'Gravesande*; the latter is chiefly supported by the *English*.

It would be too tedious to make Quotations out of each of these Authors, therefore we shall content our selves with but two or three on each Side of the Question.

1. *M. Homberg*, in his *Essai du soufre Principe*, holds, "That the chymical Principle or Element Sulphur, which is supposed one of the simple, primary, pre-existent Ingredients of all natural Bodies, is real Fire; and consequently that Fire is coeval with Body". *Mem de l'Acad. An. 1705*.

Dr. S'Gravesande goes much on the same Principle: "Fire, according to him, enters the Composition of all Bodies, is contained in all Bodies; and may be separated, or procured from all Bodies, by rubbing them against each other, and thus putting their Fire in Motion. But Fire, he adds, is by no Means generated by such Motion". *Elem. Phys.*

Again, "Fire, says the same Author, naturally unites itself with Bodies; And hence it is that a Body brought near to the Fire grows hot; in which Case it also expands or swells; which
Expansion

like a Philosopher, and if I knew the Nature of Fire, what produces it, what maintains it, and how it is extinguished.

Eud.

“ Expansion is not only observed in very solid Bodies, but in those whose Parts do not cohere; in which Case they likewise acquire a great Degree of Elasticity, as is observed in Air and Vapours”. *Ibid.*

On the other Hand: “ In the Production of Heat, says Mr. Boyle, there appears nothing on the Part either of the Agent or Patient, but Motion, and its natural Effects. When a Smith briskly hammers a small Piece of Iron, the Metal thereby becomes exceedingly hot; yet there is nothing to make it so, except the forcible Motion of the Hammer, impressing a vehement, and variously determined Agitation, on the small Parts of the Iron, which being a cold Body before, grows, by that super-induced Commotion of its small Parts, *hot*: First in a more loose Acceptation of the Word; with Regard to some other Bodies, compared with which it was cold before: Then sensibly hot; because this Agitation surpasses that of the Parts of our Fingers: And in this Instance, oftentimes, the Hammer and Anvil continue cold, after the Operation; which shews, that the Heat acquired by the Iron, was not communicated by either of those Implements, as heat; but produced in it by a Motion, great enough strongly to agitate the Parts of so small a Body as the Piece of Iron, without being able to have the like Effect upon so much greater Masses of Metal, as the Hammer and the Anvil. Tho’ if the Percussions were often, and briskly renewed, and the Hammer were small, this also might be heated. Whence it is not necessary, that a Body itself should be hot to give Heat.

“ If a large Nail be driven by a Hammer into a Plank of Wood, it will receive several Strokes on its Head, e’er it grow hot; but when it is once driven to the Head, a few Strokes suffice to give it a considerable Heat: For while at every Blow of the Hammer, the Nail enters farther into the Wood, the Motion produced is chiefly progressive, and is of the whole Nail, tending one Way; but when the Motion ceases, the Impulse given by the Stroke, being unable to drive the Nail farther on, or break it, must be spent in making a various, vehement, and intestine Commotion of the Parts among themselves;

362 CONVERSATION XXVI.

Eud. Here is my Sentiment upon that Head.
 1. What is Fire? It is a Body composed of sub-
 tile Matter and groffer Particles, agitated by
 the subtile Matter with a rapid and universal
 Motion,

“ themselves; wherein the Nature of Heat consists. *Mech. Pro-
 duc. of Heat and Cold.*

Agreeable to this is the Opinion of Sir *Is. Newton*, who con-
 ceives that “ gross Bodies may be converted into Light by the
 “ Agitation of their Particles; and Light again, into gross Bo-
 “ dies, by being fixed therein.

Again, “ Fire, according to him, is only a Body much igni-
 “ ted, *i. e.* heated hot, as to emit Light copiously: What else,
 “ says he, is a red-hot Iron than Fire? And what else is a burn-
 “ ing Coal than red-hot Wood? Or Flame itself than red-hot
 “ Smoak? ’Tis certain that Flame is only the volatile Part of the
 “ Fuel heated red-hot, *i. e.* so hot as to shine: And hence only
 “ such Bodies as are volatile, *i. e.* such as emit a copious Fume,
 “ will flame; nor will they flame longer than they have Fume to
 “ burn. In distilling hot Spirits, if the Head of the Still be ta-
 “ ken off, the ascending Vapors will catch Fire from a Candle,
 “ and turn into Flame. So several Bodies much heated by Moti-
 “ on, Attrition, Fermentation, or the like, will emit lucid
 “ Fumes, which, if they be copious enough, and the Heat suf-
 “ ficiently great, will be Flame; and the Reason why fused Me-
 “ tals do not flame, is the Smallness of their Fume; for that
 “ Speltre, which fumes more copiously, does likewise flame. Add
 “ that all flaming Bodies, as Oil, Tallow, Wax, Wood, Pitch,
 “ Sulphur, &c. by flaming, waste and vanish into burning
 “ Smoak.

“ And do not all fixed Bodies, when heated beyond a certain
 “ Degree, emit Light and shine; and is not this Emission per-
 “ formed by the vibrating Motion of their Parts? And do not all
 “ Bodies, which abound with terrettrial and sulphureous Parts,
 “ emit Light as often as those Parts are sufficiently agitated, whe-
 “ ther that Agitation be made by external Fire, or by Friction
 “ or Percussion, or Putrefaction, or by any vital Motion, or
 “ any other Cause? As for Instance, Sea-Water in a raging
 “ Storm, Quicksilver agitated in *Vacuo*, the Back of a Cat, or
 “ Neck of a Horse obliquely struck or rubbed in a dark Place,
 “ Wood, Flesh, and Fish while they putrify, Vapors from pu-
 “ trifying

Motion, with a Motion upon their Center, and with Vibration. 1. Fire is a Body; one sees and touches it. 2. This Body is compounded of subtile Matter; for in a Word, it penetrates the hardest and most solid Bodies. 3. It contains more gross Parts, since it dissolves and reduces the most massy Bodies to Powder. Could the subtile Matter alone produce so sensible Effects, finding free Passages through the straitest Pores? 4. Those gross Parts are agitated; they do not move without being moved. 5. Their Motion is a rapid Motion; the imperceptible Parts of themselves, each one in Particular, would not make so great Havock if

“ trifying Waters, usually called *Ignes fatui*, Stacks of moist Hay
 “ or Corn, Glow-worms, Amber and Diamonds by rubbing,
 “ Scrapings of Steel, struck off with a Flint. Iron hammered
 “ very nimbly, till it become so hot as to kindle Sulphur thrown
 “ upon it; the Axle Trees of Chariots taking Fire by the rapid
 “ Rotations of the Wheels; and some Liquors mixed with one
 “ another, whose Particles come together with an Impetus, as
 “ Oil of Vitriol distilled from its Weight of Nitre, and then
 “ mixed with twice its Weight of Oil of Aniseeds, &c.

“ Are not gross Bodies and light convertible into one another,
 “ and may not Bodies receive much of their Activity from the
 “ Particles of Light, which enter their Composition? For all
 “ fixed Bodies being heated, emit Light so long as they continue
 “ sufficiently hot, and Light mutually stops in Bodies, as often
 “ as its Rays strike upon their Parts. I know no Body less
 “ apt to shine than Water, and yet Water by frequent Distillations
 “ changes into fixed Earth, as Mr. Boyle has tried; and then
 “ this Earth being enabled to endure a sufficient Heat, shines by
 “ Heat like other Bodies”. *Opticks*.

As to *Boerhave's* Experiments for the Proof of elementary Fire, we must wait till he shall oblige the World with his Chymistry: In the mean Time whoever has a Mind to see more upon this Head, may consult *Dr. Shaw's new Method of Chymistry*.

the

364 CONVERSATION XXVI.

the Rapidity of their Motion did not yield any Assistance to their Smallness. 6. It is an universal Motion. Draw near the Fire on which Side you please, you will still feel its Action. 7. A Motion of Particles upon their Center; for those Parts, at least most of them, having their Extremities unequal and differently moved, must necessarily turn about, at least most of them, upon their Center. 8. Finally, this Motion is a vibratory Motion, by which the Parts go and return. When turning about upon their Center they present the Point to the Matter which surrounds them, they push it; when they present the Sides, they suffer it to return upon them with Impetuosity. Hence those Parts come and return, sometimes victorious, and sometimes vanquished. Here is the Idea of terrestrial Fire; an Idea which agrees to the Sun itself, since it enlightens, warms, sparkles and shines like terrestrial Fire.

There is a sort of Fire more compact; such is a burning Coal; and a Fire more subtle and light; that is Flame. The first is a Fire, whose Parts are not entirely separated. The second is a Fire, whose Parts being wholly separated, are darted out freely on all Sides. The burning Coal is a more violent Fire than Flame, because it contains a greater Quantity of gross Parts, which conspire to the same Effect. The Force of Motion proceeds from the Mass as well as from the Velocity; and if there is some Excess of Velocity in the Parts of the Flame,
the

the Excess of Mass surmounts it in the Parts of the Coal.

By the same Reason, Flame is sometimes stronger, and sometimes weaker. It is stronger, when it contains a greater Number of gross Parts, as the Flame of green Wood; and weaker, when the Parts, which compose it, are more minute and fine, as the Flame of Spirit of Wine. Why does the Flame of Spirit of Wine flow upon Paper, without burning it? I drench my Fingers in this Liquor: I bring them near a Wax-Candle. You see them on Fire. This Fire is scarcely perceived, because the Particles of the inflamed Liquor are so fine, and their Forces so little united, by Reason of their Separation and universal Efforts, that, notwithstanding their Velocity, they have not Force enough to divide the gross Parts of the Paper and Hand.

2. What produces Fire? All Bodies whose Motion shakes, separates, and disengages the imperceptible but ramous Parts of a combustible Body; so that those Parts being disengaged and separated may follow the rapid Motion of the subtile Matter, which slides betwixt them, and surrounds them. By the Definition of Fire, it consists in the Action of these two Species of Matter, one of which obeys the impetuous Motion of the other. Hence, Fire, the Friction of certain hard Bodies; Moisture, and Water itself produces Fire.

366 CONVERSATION XXVI.

Fire produces Fire in three Sorts of Bodies; in soft Bodies, as Wax; in liquid Bodies, as Oil and Spirit of Wine; and in hard Bodies, as Wood. Fire, I say, produces Fire in these different Species of Bodies, by separating their Parts by its Irruption into their Interstices, and joining its Action to the Efficacy of the Spring of the internal Air, and to the Motion of the subtile Matter, which encompasses the imperceptible Parts of those Bodies. Do the Particles of an igneous Body, for Example, happen to strike against Wood? They shake the Parts of the Wood by their Agitation, disengage, detach, and put them into a Condition of complying with the Motion of the subtile Matter, give Entrance to some new Matter of this Species, and second the Spring of the internal Air which plays, and by setting itself at Liberty breaks Thousands of small *Cellules*, which retained it as imprisoned; thus the Parts of the Wood are in a rapid and confused Motion, and the Wood is suddenly changed into Fire.

Dry Wood catches Fire sooner than green; because the Fire, which easily insinuates itself into the Pores of the dry Wood, in which it finds nothing but Air, can scarcely get into the Interstices of the green Wood, where the Water does not afford it so free an Access. But why does Wood that has floated kindle more easily than new Wood? Because in Floatwood the Action of the Sulphurs, whose imperceptible Parts are surrounded with much

much subtile Matter, and which at first take Fire, is no longer moderated nor bridled, if I may so say, by the Salts, whose Solidity retards the Mechanism of the Sulphurs in the new Wood. In short, Float-wood loses its Salts by the Lye which is made of them in the Water; whence it comes to pass that the Ashes of Float-wood are not proper for whitening Linnen.

If the igneous Parts are wholly separated, and have Force enough to repel the surrounding Fluid to a certain Distance, it is a Flame which issues out of the Bosom of the Wood. Are they not entirely separated, or have they not Force enough to dissipate themselves by removing the Fluid which encompasses them? It is a burning Coal. Strike the Steel: Some small Particles of Steel or Flint, which were surrounded with subtile Matter, and contracted Air, are suddenly disengaged and detached by the united Forces of the Hand, the Spring of the Air, and the subtile Matter; and turning round with Rapidity upon their Center in the Middle of this Matter, they fly out and make Sparkles shine to the Eye, like those which are darted out from a Flame, in which you let fall Filings of Iron. Do you doubt whether the Sparkles, which seem to leap out from the Bosom of the Flint, can be any Thing else but small melted Particles of Steel, or of Flint itself, violently agitated? Receive them upon some white Paper; and with a Microscope you will

368 CONVERSATION XXVI.

will see the Truth. By the same Principle, Wood of *Bambou* (that is an *Indian Wood*) gives Fire, like flint Stones, when they rub two Pieces of this Wood against one another *.

If one shut up Hay while moist, the terrestrial Spirits, with which it is still impregnated, disengaging themselves more and more by the Favour of the Spring of the internal Air, and the Stroke of the subtile Matter, come at last to swim freely in this Matter; and being hurried along by their rapid Motion they break, thrust, and dissipate all the small Parts of the Hay; thus Hay is set on Fire.

Pour Water upon Lime: The Lime heats and inflames. Why? When the Lime is made, the Heat breaks the Fibres of the Stones in Calcination, works out new Pores, and enlarges the former. These Pores, these Interstices are filled with subtile Matter and igneous Bodies. When the Lime begins to cool again, the external Air penetrates into very many of the Pores, and condenses in them by the sinking down of the Parts upon one another. The Air, the subtile Matter, and the Particles of Fire, strive to dissolve those Parts: Had they some more Degrees of Force, the Solution would happen. Pour on Water: The Matter of the Lime being extremely dried up, receives the Water, which is poured on it, with a Sort of Greediness. The Agitation of the Water,

* Journ des Sçav. p. 268. 1686. 2. Sept.

which

which penetrates it impetuously, disengages the Parts of the Fire, renders them victorious, and furnishes necessary Degrees of Force. The Parts of the Lime being forced to yield, are wholly separated: Being separated, they are darted out on all Sides without being entirely dissipated, because the external Air, which surrounds them, does likewise retain them; and this is an Ebullition; a sensible Heat, a Flame, which shines to the Eye.

In vain would you attempt to kindle a combustible Body in a Place void of Air. The burning Glass does not kindle Sulphur itself in an Air-Pump, out of which one has pumped the Air; because the Parts of the Sulphur being violently agitated, as they are not retained by the external Air, are too much dissipated to make a sensible Flame. Nevertheless if you add Salt-petre to the Sulphur, the Sulphur inflames, because the Salt-petre hinders the excessive Dissipation of the Sulphur.

Arist. Thus the Fire is kindled; the Business now is how to maintain it; its Parts being agitated endeavour to dissipate, and they pass away in Smoak, when they have lost a great deal of their Agitation. What is it that supports the Fire?

Eud. All Bodies which furnish it with Fuel; in Order to repair the Loss which it has made, as Wood, or which hinders the Dissipation of its Parts, as Ashes and the external Air. Fire is principally nourished with gross Bodies;

370 CONVERSATION XXVI.

which contain Plenty of Salts, Salt-petre, and Sulphur. Has Wood lost its Salts by floating upon the Waters? The Fire of it is the less ardent, although the Wood burns with great Velocity on that Account; and since Fire, when it is ardent, penetrates the hardest Bodies, it must have round or pointed Particles, as those of Salt-petre. The more Sulphur combustible Bodies have, the more easily they kindle. Are they without sulphureous Particles, as Water and Ashes, they scarcely burn. A kindled Coal does not fail to be preserved under Ashes without new Fuel; because the Ashes hinder its Parts from being wholly detached and dissipated.

By the same Reason, the Air contributes to the Preservation of the Fire, which it surrounds. Why is Fire hotter in Winter? Because being surrounded with a thicker Air, it is less dissipated. A Wax-Candle is quickly extinguished in an Air-pump, in which the Air no longer opposes the Dissipation of the Flame.

The Flame of the Wax-Candle owes its Preservation to the Pressure of the free Air. The free Air by its Weight and Spring presses the small Parts of Wax divided by the Heat of the Flame; these Parts being compressed ascend by the Wick, as through an Infinity of capillary Pipes, into the *Focus*, where the Resistance is least, by Reason of the successive and continual Departure of a Quantity of Particles, which pass into Flame: Thus Wax feeds the Flame.

The Flame being violently agitated strives to dissipate itself; but the lateral Air stays its Efforts. The Weight of this Air prevails against that of the Flame; and the Flame being lighter, ascends. In its Elevation, its Particles, in Proportion as they are farther distant from the *Focus*, and less perpendicular to it, give more of their Force to the Air, and their lost Forces are less repaired. Hence the lateral Parts of the Flame are dissipated, pass into Smoak, disappear, and the Flame terminates in a Pyramid; a Figure which the Flame takes so much the more easily, because this Figure is fitter to divide the Air, since it communicates less Motion to the superior Air. The Flame of a Wax-Candle seems sometimes to bound, augment and diminish in an Instant; because of the Tremulation of the Air, or because it does not always equally receive Nourishment.

What I have said of the Wax-Candle, one may say of the Lamp. Is the Lamp upon the Point of being extinguished for Want of Oil? The Flame is elevated, and its Light is thereby the more bright. That is because the Air, which detaches this weak Flame, bears it up by taking its Place. The Effort which bears up the Flame, communicates an Agitation to its languishing Particles, which animates them, and gives them that momentary Vivacity, to which they compare those unexpected Moments of Vigour, which makes us hope for

372 CONVERSATION XXVI.

the Cure of a sick Person, when he is just bordering upon the Point of Death.

Arist. But finally, how is the Fire extinguished? The Question is to extinguish it like a Philosopher.

Eud. The Fire is extinguished through want of Nourishment, or by the Excess of a too violent blowing, or by the Action of Liquors which are not sulphureous; sometimes by being too compact, and sometimes by not being sufficiently compacted; and at other Times because most of these Reasons happen to be united. 1. Fire is extinguished for want of Fuel, because the agitated Parts lose their Motion, and go off in Smoak, without others coming to supply their Place with this rapid Agitation, in which Fire consists. 2. Fire is extinguished by the Excess of too violent blowing; because excessive Blowing detaches the Flame from the combustible Body, which furnished it with Fuel. 3. Fire is extinguished by the Action of Liquors, of Water for Example; because this sort of Liquor, by running into the Interstices of lighted Bodies, stay their Particles, whose Motion they assume, which dissipates them into Smoak. Nevertheless when the Fire is violent, Water only serves sometimes to render it more ardent, because it only hinders the Diffipation of the igneous Corpuscles, and furnishes Matter to a rapid Fire. Hence, the Water wherewith Smiths besprinkle their burning Coal, only serves to inflame it

it still more. 4. Fire is extinguished in a Place too much confined; because the Corpuscles of Fire lose their Agitation in it, without being able to separate themselves. Thus, when one can get all the Vents of Caverns stopped, one effectually smothers Fire in them. If Fire lays hold on the Chimney, a wet Cloth, which you extend before it, is capable of preventing Combustion; Why? The external Air, which corresponds to the Vent of the Chimney, not being able to circulate, because the wet Cloth leaves no Access into the Chimney, hinders the kindled Soot from extending itself, from communicating its Motion, and from issuing out; it smothers it; or else the kindled Matter is detached, but being too weighty to support itself in the Air, because it is too much contracted to dilate itself, and being only sustained by an Air strongly rarified, it falls, and is extinguished after having caused some vain Alarms. 5. Pump out the Air from the Air-pump, whenever the Flame in it is no longer compressed by the Air to a certain Degree, it is dissipated and disappears.

If what is said of the Salamanders is as true, as it is probable, they extinguish Fire after a singular Manner¹. *Steno*, a famous Anatomist, affirms in a Letter written by him, that the Chevalier *Corvini* told him, that having thrown into the Fire a Salamander brought

¹ Journ. des Scav. 1667. 25. Avr. p. 94.

374 CONVERSATION XXVI.

from the *Indies*, it swelled at first, and vomited some liquid Matter with which it extinguished the Coals next to it, that it guarded itself from the Violence of the Fire during the Space of two Hours, extinguishing the Coals continually after the same Manner, when they were kindled again, and that it was still alive nine Months after.

Whatever be in that, the Secret which the *Germans* have invented for extinguishing of Fire, unites together, and sets a working at the same Time almost all the Methods of extinguishing it^m. The Experiment of it has been seen in a Cave, and in a Sort of Barrack of Plank, built in the Fore-Court of the Invalids. The Barrack was built after the Fashion of *Foires St. Germain*, upon a square Plain, each Side whereof was about 18 Foot. Its Height was about 10 Foot, taking it from the Level of the Ground, to the Beginning of the Roof; which was elevated five Foot. The Flame spread abroad on all Sides in the Cave, and in this Sort of House, was smothered all at once. Here is the Secret equally simple and ingenious.

In the Middle of a Barrel full of Water, about 22 Inches in Height, and 13 Inches in Diameter, there is a cylindrical Box of Tin, almost four Inches in Diameter, and which can contain about two Pound of Gunpowder.

^m Mem. de l'Acad. 1722. p. 143.

The Box is terminated by a long Neck, which passes through one of the Bottoms of the Barrel. A Fusee contained in this long Neck can convey the Fire from without inwardly. Should one have a Mind to make Use of this Barrel thus prepared, you set Fire to the Fusee, and thrust forward the Barrel into the Fire as much as possible. In a short Time the Box and Barrel burst; the Combustion ceases, if the Fire be not very vehement; at least the Flame is extinguished suddenly, and the Combustion becomes accessible. Whence proceeds this sudden Extinction?

Arist. The Powder being kindled, and finding Resistance in the Box, Water, and Barrel, has Leisure to be inflamed and act almost at the same Time. Being inflamed, it is dilated prodigiously, acts universally, breaks the Box, staves the Barrel, makes the Hoops fly off, and shoots out on all Sides an Infinity of small Water Spouts. The neighbouring Air, being equally compressed on all Sides at first by the Rarefaction of the Powder, stops the Circulation of the external Air from without inwardly, contracts the Flame of the Combustion by its Pressure, detaches it, and makes it quit its Hold, by the Quickness and Liveliness of its Action. The Air issues out; what remains, being extremely rarefied, no longer hinders the Flame from dissipating. The Water shot out on all Sides accomplishes the smothering of it; and wetting the whole Surface of the combu-

376 CONVERSATION XXVI.

stible Bodies, it renders them inaccessible to the Flame of the Powder, being weakened by the Excess of its Rarefaction. Thus the Fire is extinguished, according to the Rules of Physics, by a Secret which unites together, and sets a working at the same Time almost all the ordinary Methods of extinguishing it. But why does a Firebrand, when extinguished, throw out more Smoak than formerly?

Eud. The Smoak, which proceeds from kindled Bodies, or from such as are extinguished, is a Collection of gross and separated Parts, but which have not that Rapidity of Motion, which Fire requires; whether it be that they have never acquired it, or that they have lost it. The extinguished Firebrand throws out more Smoak, because the Particles, which a rapid Motion before dissipated, are united, having lost a great deal of their Force, and compose all together a Mass of gross Parts, which pass off in Smoak.

Let us now kindle again the extinguished Fire. I bring a lighted Candle near a Candle which one has extinguished, and which still smoaks; the Flame goes in Search of it.

Arist. The Reason is, because the Flame is pushed with more Force toward the Candle by the external Air, than it is pushed back by the rarefied Air, which is between it and the Candle.

Eud. This Flame quickly Lights the Candle again.

Arist.

Arist. Because the Flame finds still in the Candle Particles strongly agitated, and which require no more, in Order to be inflamed again, than a light Increase of Agitation.

Eud. I think, *Aristus*, we know sufficiently the Nature of Fire, and what produces, maintains, or extinguishes it. Would you have us henceforth to speak of different Fires, the Fires which we see upon the Surface of the Earth? As for the Fires which one sometimes sees shining in the Air, we shall speak of them among the Meteors.

Arist. The Fire, which surprizes me most, is that of Gunpowder.

Eud. Well, at the first Opportunity we shall entertain one another with this Powder; I shall tell you its Origin.

Arist. I shall speak of its Composition; I have seen it made.

Eud. We shall next attempt to discover whence its Force proceeds, and how the divers Effects of this inflamed Powder are produced.

The Original of Gunpowder, its Composition, and its Effects physically explained, will make up the Subject of our next Conversation. To Morrow at two of the Clock in the Afternoon I shall wait for you in the Garden of the *Arſenal*.



CONVERSATION XXVII.

Upon Gunpowder.

Arist. **T**HE Subject which brings us together, *Eudoxus*, has something frightful in it; and all its Usefulness consists in overturning and destroying. Nevertheless it does not want its own Agreeableness. Begin, I pray you, with teaching me the Original of Gunpowder †, as you promised.

Eud.

† The ordinary Account of the Invention of Gunpowder is false, it being evident from the Writings of *Roger Bacon*, commonly called *Fryar Bacon*, who flourished about the Year 1226, that Gunpowder was well known to him: “Thunder and Lightning, he tells us, may be produced by Art, for that Sulphur, Nitre, and Charcoal, which when separate have no sensible Effect, when mingled together in a due Proportion, and closely confined, yield a horrible Crack. A more precise Description of Gunpowder cannot be given in Words; and yet a Jesuit *Barthol. Schwartz*, some Ages after, has had the Glory of the Discovery.” *V. Shaw’s Chemistry*. p. 17.

The Explosion of Gunpowder is thus explained by *Sir Isaac Newton*. “When Gunpowder takes Fire, it goes away into flaming Smoak. For the Charcoal and Sulphur easily take Fire, and set Fire to the Nitre; and the Spirit of the Nitre being thereby rarified into Vapor, rushes out with Explosion much after the Manner that the Vapor of Water rushes out of an *Æolipile*; the Sulphur also being volatile is converted into Vapor, and augments the Explosion. And the acid Vapor of the Sulphur (namely that which distils under a Bell into Oil of
“Sulphur

Eud. To give that for certain which one esteems only probable, is imposing on the Credulity of those to whom one speaks. Accordingly, I only offer to you as probable, but as very probable, what I am going to say of the Original of Gunpowder. Who first found out the Secret of Powder in *Europe*? How did they discover it, and in what Time? Who first found it, I say? It was not a Man, if we believe an Author who wrote an Hundred Years ago, and more. *Polydore Vergil* being astonished at the Fire, Noise, and fearful Crack caused by the Inflammation of Gunpowder, appears at first convinced, that *Salomoneus* himself could not find out the Art of imitating the Thunderbolt so well. In his Astonishment, he affirms *, that the Devil, that Hell alone could invent a Secret so proper for giving the World

“ Sulphur) entring violently into the fixed Body of the Nitre,
 “ sets loose the Spirit of the Nitre, and excites a greater Ferment-
 “ tion, whereby the Heat is farther augmented, and the fixed
 “ Body of the Nitre is also rarified into Fume, and the Explofi-
 “ on is thereby made more vehement and quick. For if Salt of
 “ Tartar be mixed with Gunpowder, and that Mixture be
 “ warmed till it takes Fire, the Explofion will be more violent
 “ and quick than that of Gunpowder alone, which cannot pro-
 “ ceed from any other Cause than the Action of the Vapor of
 “ the Gunpowder upon the Salt of Tartar, whereby that Salt is
 “ rarified. The Explofion of Gunpowder arises therefore from
 “ the violent Action whereby all the Mixture being quickly and
 “ vehemently heated, is rarified and converted into Fume and
 “ Vapor: Which Vapor, by the Violence of that Action, be-
 “ coming so hot as to shine, appears in the Form of a Flame”.

Opticks, p. 317.

* Lib. 3. de inv. rerum, Cap. 13.

380 CONVERSATION XXVII.

such strange Phænomena, and for destroying Mankind. Notwithstanding having recovered from his extream Astonishment, probably after having observed that, since the Invention of Powder, War seems not to be more murdering than it was in the Time of *Charles Martel*, who without either Powder or Gun covered the Fields with Dead; he was very willing to agree to it, that a Man in his Fury might invent both Gunpowder and the Gun itself. But at the same Time he condemns, plainly and without Ceremony, the Inventor to present his Head before the Mouth of the Cannon, waiting, without moving his Foot, for the Effect and Reward of his own Invention. He ordains him, without Mercy, to the Reward of that unhappy *Perillus*, who by the Appointment of *Phalaris*, was first burnt in the brass Bull which he had invented for the Punishment of Malefactors; and the Reason of so severe a Sentence, is a Sentence taken out of *Ovid*.

*Neque enim lex æquior ulla est,
Quàm necis artifices arte perire suâ.*

For my Part, I cannot believe that the Inventor of Gun-Powder was so culpable. For in a Word, he was a Religious, a Monk, a Father of the Order of *St. Francis* †, and a skilful Chymist. At least a very constant Tradi-

† *Observ. choisies, &c. T. X. à Hall.*

tion affirmed it, more than a hundred Years ago; it was said in Verse and in Prose, and *Pancirollus** and *du Cange* affirm in their Writings, that they were so persuaded. Now, it is probable that this religious solitary Chymist hardly meditated in his Retirement the Destruction of Mankind.

In short, how did he discover the Secret of Powder? Without searching for it. It was neither Penetration of Judgment, nor Malice of Heart, nor Desire of destroying Men, nor the Rage of overturning Walls, or ransacking Towns, that taught him the Composition and Force of Powder. Chance, the Author of most Discoveries, made this to him. The religious Chymist was a Physician; and far from designing to kill any Body, he was making up some Remedies. If by that Means he laboured to make Men perish, it was unknown to him. In surveying his Remedies he had made a Mixture of Sulphur, Salt-petre, and Coal, in a Vessel. Upon this Mixture he placed a Stoneⁿ. Then having Occasion for Light, he struck the Steel. A Sparkle fell upon the Mixture, and the solitary Physician was much astonished to see at once his Mixture and Remedies on Fire, the Stone in the Air, and shot out with a Crack toward the Cieling. He easily understood what might be the Force of

* De Tormentis mural.
tirole, de Torm. mur. p. 284.

ⁿ Du Cange, T. I. 579. Pan-

382 CONVERSATION XXVII.

a Powder composed of Grains, wherein Sulphur, Salt-petre, and Coal should be predominant; and this is what they call Gunpowder, because when they knew its Force and Properties, they quickly charged Guns with it, which made Streams of Blood to flow contrary to the Intention of the religious and innocent Inventor.

Nevertheless he who invented it was not the first that knew how to make Use of it. But one of his Brethren, a Chymist like himself, found out this Use equally profitable and fatal. The Invention of Gunpowder is ascribed to *Roger Bacon* an Englishman, and the Art of using it to *Bartold* the Black, a *German*°, both the one and the other probably little conversant in the Business of War; but learned Chymists, who both equally concurred in the Recesses of their Solitude, to pour out and to save humane Blood, perhaps without thinking on it; for since the Invention and Use of Gunpowder, so much the fewer Persons have perished perhaps in Battles, as there is more Noise made in them than was made before the Use of Fire-Arms.

But in what Time did they find out this Powder and its Use, at present so famous throughout the whole Universe? It is difficult precisely to fix the Epocha of it. But it is probable that it was in the Beginning of the

° Observ. chois. & Scav. T. 10. à Hall. Observ. 12.

14th Century, and much sooner than many Authors have believed it. If we have no Monuments before this Time, which make Mention of Gunpowder, and if we have one of the Year 1338, which evidently shews that they made Use of it in 1338, in the Sieges of Towns, one ought, I think, to refer to the Beginning of the 14th Century both the Invention and Use of Powder. This Invention and Use well deserved to find a Place in History; and probably some Time before they used it in attacking Places, they had found out both Powder and the Art of using it.

Now, 1. There is no Mention made of Gunpowder in the Monuments previous to the 14th Century; I say it at least upon the Testimony of *Mirée*, *Polydore Vergil*, and *Mariana*, who assures us that before 1343, he had seen no Trace of Gunpowder in History.

2. We have a Record which proves evidently, that in 1338, they made Use of it in Sieges: For in the Chamber of Accompts of *Paris*, in an Accompt of 1338, they speak of Expences made for Powder necessary to the Guns, which were before *Puy Guillaume*, a Castle in *Auvergne*. Therefore it is probable that the Beginning of the 14th Age ought to be the Epocha of the Invention and Use of Gunpowder.

In one Word, a religious Chymist having casually made a Spark of Fire to fall upon a Mixture of Sulphur and Salt-petre, which took Fire, and shot up the Stone with which it was covered,

384 CONVERSATION XXVII.

covered, found out the Secret of Powder; another religious Chymist found out the Use of it; both the one and the other are found to have been in the Beginning of the 14th Century. Such is probably the Original of Gunpowder. What is the Composition of it?

Arist. We see every where, *Eudoxus*, what forms the most marvellous Mixtures; the Question is only to know how to match them together. But this is exactly the Point of Difficulty, which Chance sooner surmounts than the Efforts of a profound Meditation. They had seen in all Ages Salt-petre, Sulphur, and Coal; and yet always before the 14th Century they had probably been ignorant, at least in *Europe*, that Coal, Sulphur, and Salt-petre being besprinkled with Water, mixed, pounded, bruised, beat together in a Mortar, then made to pass through a Sieve, and divided into Globules, ought to make Powder, which would throw down the Walls of the strongest Places, make Warriors, Bastions and Towers to whirl about in the Air, and in one Instant carry Death farther than a Quarter of a League. Now, this Powder, so long a Time unknown, and notwithstanding so powerful, this Powder compounded of Salt-petre, Sulphur, and Coal, is Gunpowder.

Upon Casks, such as we see here, bored through in their Bases, open upward, and filled with the Rubbish of old Buildings, with fat and saltish Earth, and with Earth where
Animals

Animals have left what does not pass into the Substance of the Blood, they pour Water, which in filtering detaches by its Weight and Motion, dissolves and carries along with it into a Vessel the small Particles of Salt diffused in the Earth. Afterward they boil this Water thus charged with Salts. The Water is evaporated by the Heat. After the Evaporation, the Salts which they suffer to cool again, are united together in Form of Ice. This Ice, which is formed in Summer as well as Winter, is Salt-petre.

The Salt-petre is thrown into the Mortars of Powder-Mills, with Sulphur. Upon this Mass of Sulphur and Salt-petre they spread pounded Coal, proper for receiving and containing in its open and numerous Pores, made by the Violence of Fire, the Salt-petre and Sulphur united together. They mix five or six Parts, sometimes less, of well refined Salt-petre, one Part of Sulphur, and one Part of pulverized Charcoal. They besprinkle the Mixture with Water, to hinder the Mass, composed of Matter, which is easily inflamed, from heating too much by the repeated Blows of the Pestils, which break and bruise it in the Mortars; and least happening to set itself at Liberty by a sudden and too ordinary Inflammation, it should make the Pestils, Mortars, the Director of the Mill, and the Mill itself to fly into the Air. At last, the Matter of the Powder, being sufficiently broken, bruised and mixed, is sifted in such Sort, that passing through an Infinity

VOL. I. C c of

386 CONVERSATION XXVII.

of small Holes it falls in small Grains, to which they have given the Name of Powder, by Reason of their Smallness and Figure. In one Word, a Mixture of Sulphur, Salt-petre, and Charcoal pounded, and bruised in a Mortar, and then passed through a Sieve of Hair, and formed into Grains, or divided into small spherical Parts, or almost spherical, is the Composition of Gunpowder, of this Powder which produces so prodigious Effects.

Eud. Let us examine those Effects by the Help of Philosophy; and let us endeavour to discover their true Cause. Things in themselves the most admirable cease to affect us, in Proportion as they become more common. One has too often seen the Effects of Powder in the Firelock, to find them so marvellous, as they are in themselves. Powder never fails to astonish in the Canon, was it only by Reason of the dreadful Noise, which it causes in it, imitating the Lightnings and Thunder, so as to make it called the Canon of the Thunder of War. And who can help admiring the Force of Powder, when one sees with Horror Towers, Forts and Ramparts, rapidly shot out above Vortices of Flame and Smoak, which at once issue out from a deep Mine? They speak with as much Surprise as Dread of the infernal Machines, especially those of *St. Malo*. They exclaim against the artificial Fires. Powder in the Rockets attracts the Eyes of all. Does the Rocket ascend directly
and

and very high? Does it shoot out from its Bosom shining Stars? It is certainly a fine one, the finest that one has seen; it effaces the Stars of Heaven, and the Air resounds with Applause. There needs no more but Eyes, Ears and Senses, in Order to be affected with such like Effects; but more is necessary to discover the Cause of them, and to unfold their secret Springs. The Cannoneer, Miner, and Engineer, so familiar with the Powder, do not themselves see those Springs. Perhaps with Eyes a little more philosophical, we shall discover them. Let us enquire in the first Place after the general Cause of the Effects of Gunpowder. After that, we shall make Application of the general Cause to the Explication of some particular Facts.

The Spring of Air contained in every Grain of Powder, and in the Vacuities which the Grains leave between them; the Spring of this Air, I say, being extraordinarily bended at first, and then dilated by the Inflammation of the Powder, is, I think, the general Cause; at least the principal Cause of those astonishing Effects.

My Sentiment is probable at least, if there is plenty of Air in the Grains and Interstices of the Grains of Powder; if the elastic Force of this Air is very great, and ought to be augmented in the first Instant of Inflammation, and if finally the Springs of the Particles of Air ought to play almost at the same Time: In

388 CONVERSATION XXVII.

this Supposition, all the small *Laminae* of Air are like so many bended small Bows, which happening all to be unbended almost at one Time, ought to produce considerable Effects.

Now, 1. There is Plenty of Air in the Grain, and in the Interstices of the Grains of Powder. Whilst in the Mortars of Powder Mills, the Pestil, as you have said, breaks and divides after a Thousand different Manners, the Sulphur, Salt-petre, and Charcoal, an infinite Number of small Particles of Air flow and insinuate themselves into the Interstices of this Mixture. These Particles of Air are contained in the Grains; and the Grains, with which the Charge of a Fusée, Canon, or Mine, &c. is composed, being almost spherical, make Angles with one another, which are full of Air.

2. The elastic Force of this Air is very great; one may judge of it by the Force which compresses it, whether it be in Mortars, or when one charges a Fusée or Cannon. Thus after having kindled four Grains of Powder in a Glass Tube with a burning Mirror, one has observed that the Air of the Powder cooled again, possessed two hundred Times more Space than the four Grains ^P.

3. The elastic Force of the internal Air ought to increase in the first Instant of Inflammation. Heat, which rarefies free Air, at

first contracts the Air already condensed⁹, as Experience shews us; because the agitated Corpuscles, which penetrate at first into the *Laminæ* or Spires of the free Air, finding no Access into condensed Air, exert their Force upon the external Surface, and upon a greater Quantity of Air at a Time, because in that Case there is more in a determinate Space.

4. Finally, the Springs of the Particles of Air ought to play almost all at the same Time; for the Force of the Elasticity quickly prevails, and shoots out the Flame rapidly on all Sides. Therefore, &c.

What happens, when one puts Fire to the Powder? The Sulphur of the Powder, already filled with subtile Matter strongly agitated, takes Fire immediately: The Action of the Fire, by its sudden Motion, bends again the Springs of the Air already bent. Those Springs being put into a greater Tension, and excessively bent, are unbent both by the Excess of their Force, and by the Help of the Fire, which shakes, moves and extricates the surrounding Particles of Coal, Sulphur, and Salt-petre. The Springs being bent, throw out on all Sides inflamed Salt-petre. Hence, the Grains of Powder taking Fire successively, but with inconceivable Swiftneſs, are all inflamed almost at the same Time. Thus the Springs of an Infinity of *Laminæ* of Air imprisoned in the

⁹ Ibid. An. 1703. p. 2, 3.

390 CONVERSATION XXVII.

Grains and Angles, play almost all in an Instant, and shoot out on all Sides a Multitude of hard, round and solid Particles of Salt-petre, which unite their Forces, rudely strike against whatever opposes the Direction of their Motion, and make Fuses, Balls, Bullets, Bastions, Ramparts, Inhabitants of Towns, and almost intire Towns, fly into the Air.

This, I think, is the general Cause, at least the principal of the wonderful Effects of Gunpowder. Let us enter into a Detail, and apply this general Cause to the explaining of some particular Effects. I shall say nothing why the Powder kindles so readily. One presently conceives that the Sulphur, of which it is compounded, containing very much subtile Matter, always strongly agitated, requires no more than a light Augmentation of Motion in Order to be inflamed, and to convey Inflammation into the Charcoal and Salt-petre. Neither shall I ask of you why Powder is kindled upon the Hand without hurting it. 'Tis evident that kindled Powder ought, by Reason of its Springs unbent in the Inflammation, to possess a much larger Space than it did before, and consequently becoming more light than the Air which surrounds it, the Air ought to elevate it by the Excess of its Weight, and to hinder its Action upon the Hand: But let us explain some Problems which concern the Firelock, Cannon, Rockets, Mines, and infernal Machines.

Whence

Whence proceeds the going off of the Ball, and the recoyling of the Fusée, at the Time of Explofion?

Arist. At the Time of Explofion, the Spring of the Powder, and especially of the Air contained in the Powder, acts equally on all Sides, before and behind; equally upon the Ball and upon the Breech; after the same Manner as the Spring of Air contained in a Foot-Ball driven by two opposite Forces, acts equally toward the two opposite Parts, whence the contrary Forces come, after the same Manner, in a Word, as a bent *Lamina* tends to unbend itself from the two opposite Sides, with the same Violence. The Ball, not being able to resist the Force of the Spring, yields according to the Direction which it receives from it; and this is the Departure of the Ball. The Breech, being no more able to resist the Force of the Spring, yields according to the contrary Direction which it receives from it. And this is the recoiling of the Firelock, which sometimes throws down the weak Shooter, sooner than the Prey.

But why does a long Firelock carry farther than a shorter one equally charged; provided the Excess of Length is not too great?

Eud. In the longer Firelock more Powder is kindled, since the Powder, which is successively kindled, remains in it longer Time exposed to the Inflammation. The Inflammation

392 CONVERSATION XXVII.

on of a greater Quantity of Powder, being longer Time wholly contained in the Chamber of the Firelock, strikes more Blows, and ruder Blows. The Ball being struck more rudely, receives the more Force; and with more Force, it ought to go farther. It reaches to kill a wild Duck, notwithstanding the Precaution which he had taken to place himself in the Middle of a Pond, where he might safely have defied the Force of a shorter Firelock. If the Excess of Length is too great, it diminishes the Effect of the Ball; because the Ball is thrust back inwardly into the Firelock by the Violence of the Air which enters again, or strives to enter after the Inflammation. Hence, *Vossius* asserts that the Length of a Cannon ought not to be more than thirteen Foot^r.

If one shoot very close, so that the Mouth of the Firelock touch him, who receives the Blow, the Wound is lighter, at least so far as we are informed.

Arist. In this Situation, the internal Air cannot come out freely from the Firelock; because between the Mouth of the Firelock and the Body which it touches, there is not a Passage large enough; and consequently it opposes itself the more stubbornly to the Direction of the Ball, and diminishes its Effort; the Effort

^r De Nili origine; Journ. des Scav. 1666. p. 387.

being

being deadened, wounds more lightly. I believe this Reason is good enough. Nevertheless I frankly own that I would not make the Experiment upon any Body, nor willingly allow any Body to make it upon me.

Put a little Powder into the Chamber of the Firelock, under the Ball; but over the Ball, put a great deal. Ram down the Firelock, as usual; the Shot will make a great Noise, and little Effect.

Eud. The Noise will be great, because all the Powder will take Fire, the Fire being able to pass from that below to that above, and because all the Powder being inflamed, will cause in the Air this impetuous Tremulation, which makes the great Noise. The Effect of the Ball will however be very inconsiderable; because the Ball will only be pushed forward by the small Quantity of Powder, which is below. The greater Part, which is above, will serve rather to deaden the Force of the Ball, than to augment it.

So that, if you are disposed to place your self boldly before the Mouth of a Firelock, at some Distance, you will safely receive the Ball into your Hand or Breast. You will have the Glory of knowing how to charm Fire-arms, and you will be infallibly invulnerable, without Compact, or Sorcery. A Philosopher explains such Experiments; but is too wise to make 'em.

It

394 CONVERSATION XXVII.

It would be useless to demand whence the recoyling of the Cannon and the Departure of the Bullet proceed at the same Time.

Arist. 'Tis evident that the Cause, which makes the Firelock recoil and the Ball to go off, makes also the Cannon recoil, and the Bullet to go off. But why does the Bullet advance so far, while the Cannon recoils so little, or recoils only some Paces?

Eud. Because there is as much Force required to make the Cannon with its Carriage recoil some Steps, as to convey the Bullet a long Way; since, without mentioning the Resistance which proceeds from the Friction that it makes in recoiling, the Cannon with its Carriage recoiling very little, and the Bullet carried a good Way off, are almost in the reciprocal *Ratio* of Mass and Velocity; in Proportion as the Bullet has more Velocity, the Cannon has more Mass. If the Bullet has an hundred Degrees of Velocity, while the Cannon has only one; the Cannon has an hundred Degrees of Mass, or thereabouts, while the Bullet has only one; and to carry an hundred Degrees of Mass one Pace, as much Force is necessary, as to carry one Degree of Mass an hundred Paces; so that the Cannon, in recoiling with as much Motion as the Bullet has, ought scarcely to advance one Pace, while the Bullet advances an hundred.

But

But while the Powder is inflamed in the Cannon, if the Touch-hole happen to be stopped, the Cannon bursts. Why?

Arist. 1. The Powder being inflamed in the Bottom of the Barrel, and in that Case not being able to come out in any Sort, nor to relieve itself, if I may so speak, by the Touch-hole, unites its Efforts against the Sides of the Cannon.

2. The external Air, which cannot enter by the stopt Touch-hole, cannot act upon the Inflammation in Order to hasten its issuing out; it opposes it also by the Mouth of the Cannon, so much the more, because it cannot circulate, Wherefore the kindled Powder makes the greater and more durable Efforts, from the Axis of the Barrel, toward the Circumference of the Cannon. This Excess makes it burst, because it is more easie for the Powder to make a Passage for itself at once through the Sides of the Cannon, than to wait for setting itself at Liberty by thrusting the Ball, notwithstanding the Resistance of the Air, all the Way from the Breech to the Mouth of the Cannon. When Bodies have any Difficulties to surmount, they always begin with overcoming the least. They have their Manner of acting, their Laws, and their Customs, which they observe inviolably from the Beginning of the World, being much more exact and constant in this Point, than the most Part of intelligent

396 CONVERSATION XXVII.

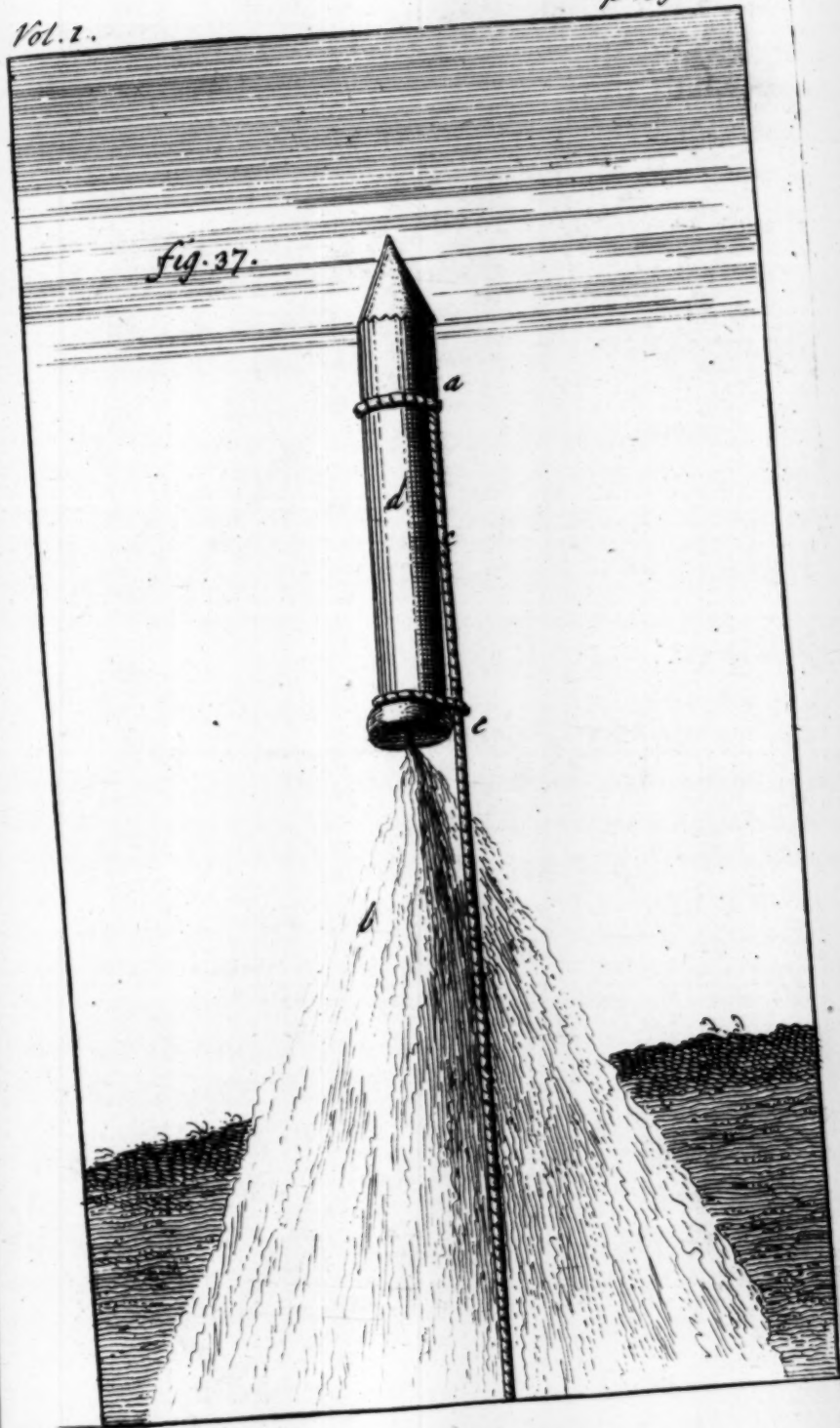
gent Beings, which only have more Knowledge in Order to discover more Extravagance.

Eud. As for the dreadful Noise of the Cannon, it is easily comprehended. — A great Quantity of kindled Powder is prodigiously rarefied in the Inflammation by the Action of an Infinity of Springs, which are unbent almost all at a Time. This strange Rarefaction strikes, compresses, and drives away a great Mass of Air; the different Parts of this contracted Mass, happening to be restored with an Acceleration of Motion, are compressed again in the Point of Reunion; the Dilatation is repeated. Hence, this Tremulation of the Air which causes the terrible Noise and Crack, which the Echos of the Mountains and Rocks strive to augment, as it were, through Emulation.

The Rocket, (*a*) *Fig. 37.* has nothing terrible in it, nor surprizes in the least, especially when one knows what makes it ascend, while the Flame (*b*) issues out below.

Arist. The Spring of the Powder, or of the Sulphur, Salt-petre, Coal, and Air contained in them, makes the Rocket ascend, as it makes the Firelock or Cannon recoil. In the Inflammation this Spring makes an universal Effort, and acts both toward the Center of the Earth, and toward the Sky. The Effect of the Action toward the Center of the Earth, is to make the Powder or inflamed Matter issue out,

fig. 37.



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out, which finds a Passage through the inferior open End. The Effect of the Action of the Spring towards the Sky, is to make the superior Powder or the inflammable Matter to ascend, and also the Tube which contains it, without affording it any Passage. After the same Manner as the Action of the Powder toward the Breech makes the Firelock or Cannon recoil, because it finds no Passage in the Breech; after the same Manner the Action of the Powder or inflamed Matter toward the Sky, not finding any Vent in the upper End of the Rocket, makes it recoil and ascend, and obliges us to carry our Eyes after it toward Heaven.

But for what Use serves the Rod (*c*), which they fasten to the Rocket?

Eud. That is to preserve its perpendicular Direction. Without the Rod the Center of Gravity would soon be above the Center of Figure (*d*); since the Powder or inflamed Matter issues out every Moment through the inferior Passage. In that Case the Part which contained the Center of Gravity would outweigh the other; and by Reason of the small Inclination of the Rocket, it would make a Semicircle in the Air, overturn itself, and descend again, since the closed End would be towards the Earth; the Rocket would move from on high downward, instead of moving from below upward. But when the Rod is fastened

398 CONVERSATION XXVII.

fastened to the Rocket, the Center (*e*) of Gravity of the whole Compound of Rocket and Rod is below the Center of Figure. This Center continually descends, so far is it from ascending, in Proportion as the Rocket is elevated. Wherefore the inflammable Matter is always above it; and thus the Rocket preserves its perpendicular Direction.

Arist. But when the Rocket seems to be elevated as far as the Clouds, why do we at once see sparkling Stars arise?

Eud. Those Stars so brilliant were nothing less than brilliant Stars a Moment before they were seen. They were small solid Balls composed of Charcoal, Sulphur, and Salt-petre, but wherein Salt-petre was predominant. These small Balls were contained above the rest in the Rocket. Being placed above the rest of the Rocket, they took Fire last of all. The Fire threw them out, and scattered them on all Sides. The small Particles of Salt-petre, solid, round, and infinitely fit for Motion, being rapidly shot out from all Sides by the Violence of the kindled Sulphur and unbent Springs, communicate the Motion and Vibrations which they have received to the Matter of the Light. This Matter being more subtle and fine than the Air, but diffused in the Air from the small inflamed Ball to our Eyes, communicates to our Eyes the Vibrations which it has received; and those Vibrations
cause

cause in the Soul the Splendor of little Stars, which we think to find in the Air, and at the Sight of which People being surprized, and judging rather by the Report of the Eyes than by that of Reason, cry out more in an Instant, than ever they did upon seeing the Heaven adorned with Stars formed by the Hands of the Creator.

From the agreeable Effects of the Rocket we must at last pass to the terrible Effects of Mines.

Arist. An almost infinite Number of Springs being contained in a great Quantity of Powder, happening to be unbent almost all at a Time in the Inflammation, and not finding Room enough to extend themselves in the Stoves, Fougades or subterraneous Chambers, agitate the Vaults with a strange Violence, shake them, detach them, and make the Half-Moons, Towers and Ramparts fly far off in the Air; and those who defended them are astonished to find themselves suddenly whirled into the Air.

Eud. But why has not a Mine its Effect, that is countermined?

Arist. Bodies in moving follow the Direction in which they meet with least Opposition. The Powder kindled in the Mine that is countermined, finds a free Passage, and is in Part exhaled through that. The more of it is exhaled through that, the fewer Efforts it makes

400 CONVERSATION XXVII.

makes against the Vault and solid Parts of the Mine. Hence the real Efforts are ineffectual, and the Miner being confounded grows pale, and rages to see the Enemy at Ease over his Mine in Fire.

I think Mines in Fire ought to have very much Relation to infernal Machines, and to produce almost the same Effects by the same Principles.

Eud. The infernal Machines are Machines of War, in which Powder by an extraordinary Inflammation produces horrible Effects, proper for representing to us by the Horror, which it diffuses, the frightful Image of the Fires of Hell. In Order to our having some Idea of them, it is sufficient to bring to Mind the infernal Machine which was designed for burning *St. Malo*, but which was only fatal to the Engineer.

This Machine was made in Form of a Vessel. It had thirty four Foot in Length, and eighteen in Height, an Hold and three Bridges. There was Sand in the Hold. The first Bridge was filled with twenty Thousand Weight of Powder, with a Foot of Brick-work above it. The second Bridge was adorned with six Hundred Firebombs and Carcasses, and two Foot of Brick-work above them. The third Bridge over the *Gaillard* was loaded with fifty Barrels with Iron Hoops, full of all Sorts of Fire-Works. The Deck
was

was contrived for conducting Fire to the Primes and Powders. Such almost was the infernal Machine*, which might have caused a general Conflagration, and with which *England* broke some Glass-Windows of *St. Malo*.

For what Use serves the Sand in the Hold?

Arist. The Machine is thereby the more weighty; being more weighty, it draws more Water; drawing more Water, it changes the Direction with greater Difficulty: In Order to change it, a greater Mass, a greater Bulk of Water must be removed. Now with the greater Difficulty the Machine changes Direction, the more certainly the Fire-Works which issue out of it reach the Scope.

But for what Use serves the Brick-work over the Powder?

Eud. You conceive that sufficiently, *Aristus.* The Brick-work retards the Action of the Powder upon the Carcasses, Bombs, and Engines. In this Delay, more Powder is kindled; consequently more Motion is communicated at once; and a greater Force produces a greater Effect. Let us imagine that the Barrels of Powder take Fire, and that the Springs of the Grains of Powder are set a going all at a Time. We shall see the Carcasses, red Bullets, and Bombs fill the Air with Fire, fall,

* Mem. d'Artillerie de M. de St. Remi, T. I. p. 371. Seconde Edition.

402 CONVERSATION XXVII.

break and burn all that comes in their Way. Or rather being content with knowing the Original and Composition of Gunpowder, and the physical Cause of its divers Effects, let us spare our Imagination so terrible a Spectacle, which Rage alone seems to have invented.

An Effect of Fire more salutary, peaceable, and agreeable, is to drive away Cold, and to produce Heat. Will you have us make Heat and Cold the Subject of our next Conversation?

The End of the First Volume.

